HOW TO GET A ROBUST GREEN NEW DEAL THROUGH CONGRESS: DETERMINING THE PHILOSOPHY, THE COST, AND THE SUBSEQUENT POLITICAL APPROACH

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ABSTRACT

The United States has not engaged in rapidly decarbonizing its economy for two reasons: because there are unpleasant nuances, and the politics are complicated.

The first sector of the economy which is on track to be fully decarbonized is the electric grid. Within this facet of the economy, there are difficult questions to answer in terms of what the role of non-renewable energies (i.e., nuclear energy and CCS) are. In short, the reason why is because they are not the most environmentally friendly options, but because they can help the United States attain a net zero carbon economy, they have roles to play. Another important facet of decarbonizing the economy is that there is a strong sense of urgency behind that sentiment, and that urgency is bolstered by extremely consequential positive feedback loops such as wildfires and thawing permafrost.

After these questions are answered, the question of cost comes into play, and this paper calculates the cost of attaining a zero carbon emissions electric grid. The reason for doing so is because President-Elect Biden's plan is for America to have that by 2035 by spending $1.7 trillion. To verify this plan, data on five states with diverse energy portfolios from the Energy Information Administration (EIA) are collected and analyzed to project the total cost for the nation. Following these calculations, the energy demand of transportation is factored in, which reveals that the President-Elect's number of $1.7 is within an accurate range.

Once these values are calculated, it becomes apparent that the cost for a zero carbon emissions electric grid is not that much relatively speaking. The range of costs annually is anywhere between $76 billion to $182 billion. Given the relatively low cost of this policy on an annual basis, and given the changes in American politics following 2020, a window is open for a new way to politically communicate this policy in terms of the United States' capacity to run up a deficit.

ACKNOWLEDGEMENTS

Special thanks to my thesis advisor, Liam Phelan, who's insight and knowledge provided me with the right mindset and approach throughout this process. He also taught me how to think deeply about the issues surrounding climate mitigation and allowed me to grow as a climate change philosopher.

I would also like to thank the many professors who instructed me throughout my climate change studies and catalyzed and fostered my evolution. Notably, Simon Huss introduced me to physics and helped me find my intuition with physics. Raghuveer Parthasarathy put me on the energy/climate path by explaining the physics of renewable energy and the environment to me. And Gregory Bothun instilled the feelings within me of the dire situation we face as a civilization with respect to climate change and the unsustainability of ecological overreach.

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EXECUTIVE SUMMARY

The Energy Policy and Climate (EPC) Master of Science program at Johns Hopkins University Advanced Academic Programs allowed me to grow as an energy, climate, and environmental policy analyst, philosopher, calculator, and communicator. The Capstone Project, which is what this research paper was written for, induced me to aggregate and synthesize two years of policy knowledge, thought, and calculative ability to conduct this research thesis. When I enrolled in the EPC program, I did so with the intent that I would be able to produce a research thesis of this caliber, and hopefully move hearts and minds with respect to the climate crisis.

Throughout the course of this Capstone Project, I demonstrate primarily three compelling realities. The first is that the pathway to a net zero carbon emissions electric grid, let alone a net zero carbon economy, is complicated with a tremendous amount of nuance. This forces anyone who desires America to evolve into a net zero emissions economy to think deeply about the challenges we face and not have short-term perspectives. The second is that the cost of developing a net zero carbon emissions electric grid is not that expensive, relatively speaking. The cost to developing that within the next ten to twenty years is around $1-$2 trillion, which is not that much considering the size of the American economy, as well as the national deficit and debt. The third is that there are avenues by which this can be politically communicated to transform these ideas into reality. Bold climate action has not begun in America for a handful of reasons, and one of those main reasons is that there has not been savvy enough communication by our climate-minded leaders. If they were to reframe their messaging, especially within the context of the fallout of the 2020 pandemic, and how this moment feels akin to that of the 1930s and 1940s, perhaps that can accelerate the process of transforming the American economy into a sustainable one.

INTRODUCTION

Why am I writing this?

This thesis was written for the Johns Hopkins University course *AS.425.800.81.FA20 Research Design for Capstone Projects in Energy and Environmental Sciences*. However, the reason for choosing this topic is because I have a deep desire to play a role in facilitating bold climate action. As someone who has studied this issue for a few years and attained a robust sense of climate change, I felt as though it was my responsibility to write a compelling thesis paper about this topic, which in turn could eventually persuade others.

What will I answer?

This thesis intends to answer some of the biggest questions about climate philosophy, physics, policy, and politics. Specifically, this thesis attempts to answer what the core goals of a Green New Deal are, what the nuances are and how they may be ethically justified, why this is something to care about, how a net zero carbon emissions grid is possible, how much will it cost, and how can political barriers be overcome in a post 2020 political era.

For whom is this intended?

This thesis is intended for policymakers, activists, philosophers, and professors.

OUTLINING THE PHILOSOPHY OF A GREEN NEW DEAL

The philosophy behind any Green New Deal-type proposal will inform and provide insight for efforts to shepherd the proposal through Congress. But, because these efforts could be impeded by a variety of difficult decisions/questions, it is important to flush out these problems ahead of time and craft a philosophy consistent with the intent of a Green New Deal-type proposal. An example of a difficult decision/question may be: does carbon capture and sequestration (CCS) have a prominent role, if a role at all within a Green New Deal? Or what about nuclear energy? These questions are important because they are methods of pragmatically dealing with climate change, but they could pose other problems that will be discussed later. This is important to keep in mind because short-term solutions must not be preferable over medium-term and long-term solutions when addressing climate change.

Why it is called "a robust Green New Deal"

It is important to mention the decision behind identifying this thesis as getting "a robust" Green New Deal through congress, because those words are carefully chosen. First off, the word "a" specifies that *a* Green New Deal is the goal, not necessarily *the* Green New Deal. The simple reason for choosing *a* versus *the* is because *the* Green New Deal did not get through Congress. Therefore, that Green New Deal is not the law of the land and the required degree of climate action is not being carried out in this country. Because the whole point is that the United States of America engages in said climate action, a fundamental criterion is that that action takes place. Also, since the phrase "Green New Deal" is now more commonly understood by the electorate as a policy in which the United States engages in decarbonization, that is the phrase used throughout this paper.

Another carefully chosen word is "robust." The reason for why this is the word that was chosen over words like optimal and best is because it is basically impossible to define what that means within the context of a Green New Deal and what is necessary for climate change. Since the climate system is incredibly complex, and since the American political system pretty much never allows for whatever the "optimal" or "best" policy is and considering the messy process that Congress and American political discourse endure during a tumultuous political battle, whatever is best or optimal at some point is thrown out the window. Therefore, hypothesizing about whatever is best, optimal, or anything along those lines, is essentially a fool's errand.

What does the "Green" in Green New Deal mean?

The term green is often associated with that of environmentally friendly, or climate friendly. And given the history surrounding the term "New Deal," the "Green" adjectives evoke the notion of a New Deal which is an environmentally friendly one, or a climate-friendly one. Therefore, the "Green" may mean, a national project intended to deal with climate change. However, if the mission is to "deal with climate change," it is necessary to ask, "what does that mean?"

Dealing with climate change can be defined as engaging in *climate action*. Climate action is a critical term because climate action is to "[t]ake urgent action to combat climate change" (United Nations, "Climate Change – United Nations Sustainable Development"). There are two facets of engaging in climate action, mitigation, and adaptation. Mitigation is "[r]educing emissions of and stabilizing the levels of heat-trapping greenhouse gases in the atmosphere."[1] Adaptation is "[a]dapting to the climate change already in the pipeline."[2] Therefore, dealing with climate change by engaging in climate action would entail tackling climate change with the two-pronged approach of mitigation and adaptation.

The philosophical approach which drives the motivation to mitigate climate change is quite simple, and the best way to sum this notion up is to reference a speech about the largest initiative to mitigate climate change, the Paris Climate Accords. As Thorgeirsson stated at the United Nations Framework Convention on Climate Change, warming should be capped at "well below 2 degrees C aiming to be as close to 1.5 degrees C as possible."[3] Otherwise, we will have to wrestle with "profound moral implications given that climate change has greatest impacts for exposed and vulnerable nations and on

[1] "Climate Change Adaptation and Mitigation" "Climate Change Adaptation and Mitigation." NASA, NASA, 18 Sept. 2020, climate.nasa.gov/solutions/adaptation-mitigation/.
[2] "Climate Change Adaptation and Mitigation." NASA, NASA, 18 Sept. 2020, climate.nasa.gov/solutions/adaptation-mitigation/.
[3] "Thorgeirsson - Paris and the Moral and Economic Imperatives of Climate Change Action." UNFCCC, UNFCCC, 15 July 2015, unfccc.int/news/thorgeirsson-paris-and-the-moral-and-economic-imperatives-of-climate-change-action.

vulnerable populations within all nations".[4] Simply put, it is immoral to allow Earth to warm by 2 degrees C because if that occurs, an unfathomably amount of people undoubtedly will unjustly suffer. Therefore, the conclusion could be drawn that any effort to mitigate climate change and meet the threshold of 2 degrees C, with the intent to meet the threshold of 1.5 degrees C, can be regarded as a moral endeavor. This is the underlying philosophy for why climate change should be mitigated, and why Congress should pass a robust Green New Deal.

Lastly, a Green New Deal essentially means that electricity will still be reliably accessible. This is an important facet of a Green New Deal because if electricity is unreliable/intermittent, then it poses other societal problems, and therefore the policy would be in danger of not passing the ultimate barrier of political scrutiny. A key reason is that within American culture, there is the sentiment that everyone deserves to have luxuries instantly and reliably. Americans want to watch television, charge their phones, and transport themselves from point A to point B reliably. Therefore, if constantly having reliable power is a prerequisite for a Green New Deal, a critical concept must be understood which is "base load capacity."

Base load capacity is "[t]he generating equipment normally operated to serve loads on an around-the-clock basis.[5] Simply put, the base load capacity is being able to reliably provide power 24/7 which is difficult to attain with current renewable energy technologies since the sun is not always shining and the wind is not always blowing.

Therefore, different energy technologies must be utilized to adequately engage in climate mitigation by establishing a zero carbon emissions electric grid.

[4] "Thorgeirsson - Paris and the Moral and Economic Imperatives of Climate Change Action." UNFCCC, UNFCCC, 15 July 2015, unfccc.int/news/thorgeirsson-paris-and-the-moral-and-economic-imperatives-of-climate-change-action.
[5] "Glossary." Glossary - U.S. Energy Information Administration (EIA), www.eia.gov/tools/glossary/.

The Nuances of Mitigation

There are nuances within the notion that any mitigation effort is moral. Before delving into these nuances, renewable energy and clean energy must be defined. Renewable energy "is energy from sources that are naturally replenishing but flow-limited".[6] The five major types of renewable energy sources are biomass, hydropower, geothermal, wind, and solar. "Clean energy is energy that is produced through methods that do not release greenhouse gases".[7] Therefore, if an energy is renewable, it is clean, but it is not necessarily renewable if it is clean.

For example, nuclear energy is a great topic of discussion in terms of the philosophy of mitigation because it often cuts at the heart of the issue of thinking in the short run as opposed to the medium or long run. The best way to approach the question of the viability of nuclear energy is to analyze its upsides and downsides, and then use that analysis to determine what its role in climate action ought to be.

The upsides are clearly substantial. For starters, nuclear energy is a clean energy and is America's "largest source of clean energy," which means that it can play a critical role in terms of "reduc[ing] carbon emissions".[8] Nuclear also has a tremendous power output, and the "largest nuclear power plant in the United States" has a "generating capacity of about 3,937 MW".[9] As of now, wind and solar are nowhere near that output in terms of a single plant in the United States. The last and perhaps paramount upside of nuclear energy is the fact that it can serve as a base load clean energy. Because "[n]uclear energy is the only carbon-free source in our grid that can supply power around-the-clock",

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[6] "Renewable Energy Explained." U.S. Energy Information Administration (EIA), EIA, www.eia.gov/energyexplained/renewable-sources/.
[7] "What Is Clean Energy?" Busch Systems, www.buschsystems.com/resource-center/knowledgeBase/glossary/what-is-clean-energy.
[8] "Climate." Nuclear Energy Institute, www.nei.org/advantages/climate.
[9] "How Much Electricity Does a Nuclear Power Plant Generate?" U.S. Energy Information Administration (EIA), www.eia.gov/tools/faqs/faq.php?id=104&t=3.

nuclear energy thus has a pivotal role in America's energy portfolio.[10] Or, at the very least, it has a pivotal role to play until other zero-carbon technologies can provide a base load such as utility scale storage, solar thermal, and ocean thermal energy conversion (OTEC).

However, with respect to the medium run challenges of nuclear energy, it is important to mention that "37 gigawatts of U.S. nuclear capacity is overly exposed to flood risk" which reminds us that as the impending consequences of climate change become more pronounced, nuclear power plants will become increasingly at risk.[11] And while discussing the consequences of climate change, it is important to know that regions in America throughout the next several decades "are projected to face water scarcity," which threatens the viability of nuclear power plants, and if they can provide power as reliably as they have over that time frame.[12] This is important because the electricity generated from nuclear energy requires more water than that of any electricity generating entity. According to The Routledge Handbook of Energy Security by Sovacool, nuclear energy requires about "400" gallons per MWh.[13] Therefore, using any electricity generating method which requires a massive use of water is an insecure one. And, when one considers the other threats of climate change, nuclear is not a wise option because of storms (hurricanes and floods), heat waves, and other unforeseen possibilities. Obviously if a hurricane or a flood were to dismantle a nuclear facility, that has the potential to be disastrous. But heat waves are also a problem because if transmission or distribution from the nuclear facility is disrupted, hundreds of MW could instantly disappear from a city that desperately needs the electricity because of a surge of active A/C units and hospitalizations because of an increase in heat strokes, etc.

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[10] "Infrastructure." Nuclear Energy Institute, www.nei.org/advantages/infrastructure.
[11] Ellfeldt, Avery. "Mounting Climate Impacts Threaten U.S. Nuclear Reactors." Scientific American, Scientific American, 20 Aug. 2020, www.scientificamerican.com/article/mounting-climate-impacts-threaten-u-s-nuclear-reactors/.
[12] Ellfeldt, Avery. "Mounting Climate Impacts Threaten U.S. Nuclear Reactors." Scientific American, Scientific American, 20 Aug. 2020, www.scientificamerican.com/article/mounting-climate-impacts-threaten-u-s-nuclear-reactors/.
[13] Sovacool, Benjamin K. The Routledge Handbook of Energy Security. Routledge, 2013., 185

Nuclear energy is also a product of the archaic and monolithic style of providing energy to ratepayers. The Edison style of developing a high output power plant and building transmission to connect ratepayers to their power has not changed much since the 19th century, and nuclear power exhibits the same model. However, because energy models such as "microgrids can provide unparalleled reliability and resilience" in the face of climate change, it can be concluded that nuclear power plants may not be a viable solution for a 21st century energy system because they are not consistent with climate adaptation practices.[14]

Unfortunately, this thesis will not take a deep dive into microgrids and their role in a Green New Deal, but what should be understood is that they have the potential to make the cost of a net zero emissions electric grid a lot cheaper because they will lead to a much more efficient energy system which does not require as much long-distance transmission. Because of that shorter length of transmission and less energy losses, less electricity will need to be generated, thus requiring less spending on clean energy proliferation. And of course, the flexibility and resiliency of microgrids have the potential to reduce energy infrastructure costs in the long run because less transmission and less powerplants will have to be rebuilt following climate shocks. Therefore, microgrids are prime examples of climate adaptation.

Lastly, with respect to nuclear energy, the prospect of an ecological catastrophe cannot be forgotten. One inescapable challenge of nuclear energy is properly storing nuclear waste, which is quite possibly the least biodegradable material civilization has ever produced. Therefore, the United States must find a way to store it such that future generations do not accidentally expose the material. According to the United States Nuclear Regulatory Council, the half-life for this waste is about "24,000 years".[15] This is an extremely long period of time which encompasses many generations, but more importantly, a lot can

[14] Guccione, Leia. "The Micro(Grid) Solution to the Macro Challenge of Climate Change." Greenbiz, 14 Oct. 2013, www.greenbiz.com/article/microgrid-solution-macro-challenge-climate-change.
[15] "NRC: Backgrounder on Radioactive Waste." U.S. NRC, www.nrc.gov/reading-rm/doc-collections/fact-sheets/radwaste.html.

occur in that time, specifically dramatic climate change. To put this in perspective, during the last Ice Age, which ended around 12,000 years ago, CO_2 ppm levels were about 180.[16] At this time, Manhattan was under "2,000 feet" of ice, "and possibly more".[17] But as the Ice Age ended, CO_2 ppm levels sharply rose to about 280, and the thousands of feet of ice covering Manhattan melted as Earth changed dramatically. But now in 2020, CO_2 ppm levels are skyrocketing and are currently at 413 ppm according to calculations at the Mauna Loa Observatory.[18]

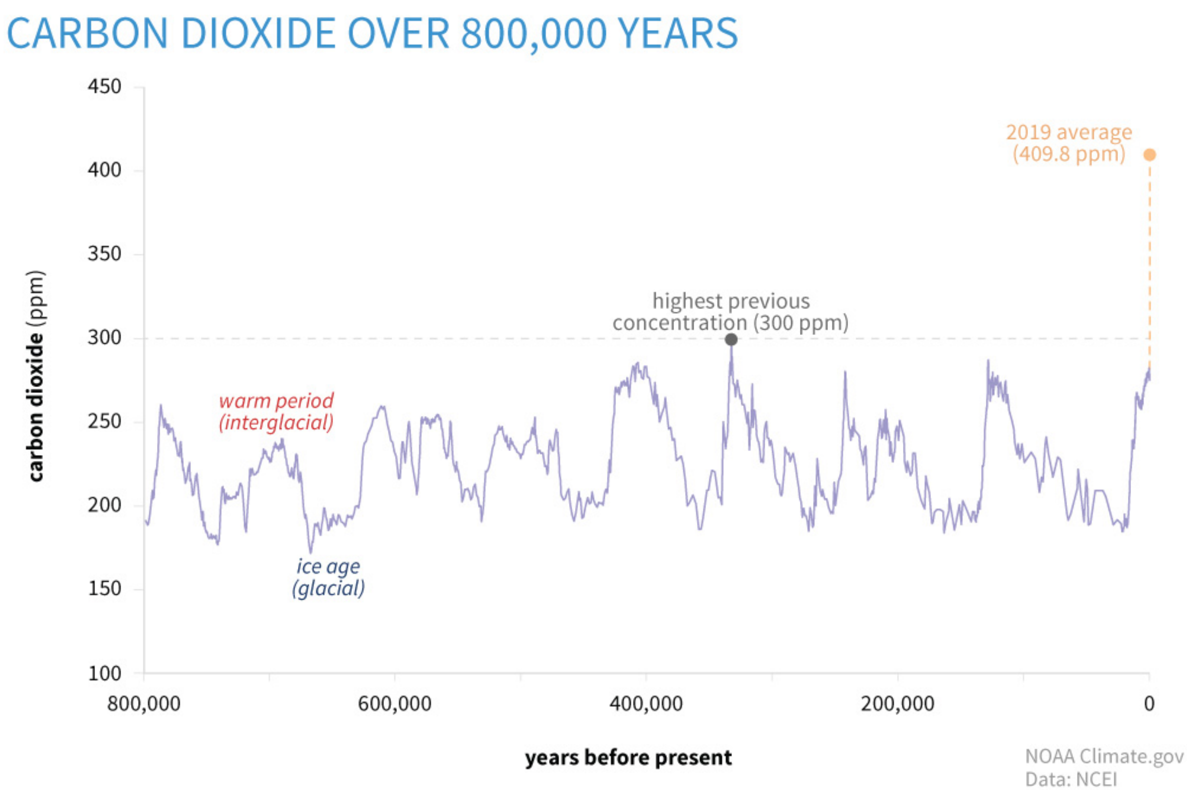

Figure 1: Carbon Dioxide over 800,000 Years[19]

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[16] "Climate Change: Atmospheric Carbon Dioxide: NOAA Climate.gov." Climate Change: Atmospheric Carbon Dioxide | NOAA Climate.gov, 14 Aug. 2020, www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide.
[17] Broad, William J. "How the Ice Age Shaped New York." The New York Times, The New York Times, 5 June 2018, www.nytimes.com/2018/06/05/science/how-the-ice-age-shaped-new-york.html.
[18] "Earth's CO2 Home Page." CO2.Earth, www.co2.earth/.
[19] "Climate Change: Atmospheric Carbon Dioxide: NOAA Climate.gov." Climate Change: Atmospheric Carbon Dioxide | NOAA Climate.gov, 14 Aug. 2020, www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide.

This means that Earth may look totally different within a few hundred years, which would require the United States to store nuclear waste as resiliently as possible. Otherwise, if the nuclear waste is improperly stored, today's actions would be displacing a catastrophe on future generations, which is exactly what a Green New Deal is intended to avoid from occurring.

Therefore, after weighing the upsides and the downsides of nuclear energy, it is reasonable to state that nuclear energy has a role to play in climate action, but it is not a silver bullet solution because of the possibility of ecological catastrophe and the fact that the changing climate is posing unprecedented problems. Hence, it is essentially immoral to build new facilities because those government funds would be better served toward alternative base load solutions such as utility scale storage, solar thermal, OTEC, and more. But because those alternative solutions are not available as of now (or are at least not low-cost and available at the scale required), nuclear energy power plants have a critical role to play in terms of acting as a clean energy base load technology and should continue to be operational because if they are decommissioned, then they will most likely be replaced by natural gas fired-power plants, which of course would exacerbate climate change. Therefore, if many American nuclear power plants are decommissioned, that is an immoral decision, except if they are replaced with other clean energy alternatives.

It is also necessary to ask, what is CCS's role in mitigation efforts? It is still invasive, may have adverse effects not yet known, and relatively expensive as of now. However, it may be the most viable mitigation tool in some parts of the country where renewable energy resources are scarce, and it is impractical to transmit renewable energy to that region.

Another gray area of moral vs immoral decisions within the realm of mitigation is the prospect of this technology. The EPA has a good definition of CCS, which is that it "is a set of technologies that can greatly reduce CO_2 emissions from new and existing coal- and gas-fired power plants and large industrial sources".[20] However, CCS is a controversial topic within the realm of climate action for a handful of reasons.

The first reason is that this can lead to serious ecological problems. The storage process, which includes injecting the captured CO_2 into a sub-seabed, has the potential to lead to leakages, which can have impacts on the local ecology. Because this is a relatively new technology, there is not too much research on the topic, but there are some conclusive scientific journal articles which have concluded that leakage has occurred and led to ecological impacts. A Marine Environmental Research journal article discovered that "long-term exposure to elevated levels of CO_2 in the overlying seawater, as a result of a... sub-seabed leak from a CCS reservoir, can impact upon the benthic biogeochemical processes associated with organic matter cycling".[21] It should be noted, that this is an impact that is especially difficult to project the outcome of, hence the long-lasting effects of CCS are unknown. It is also worth noting that this is not the only scientific journal article about negative environmental impacts from CCS, but there is still sparse literature on the subject relatively speaking. It should be anticipated that as this technology becomes more developed and deployed, more research on the subject will be conducted.

Another reason is the fact that the technology may be incredibly expensive. This specific subject will be discussed more in depth in the methods section, but the simple comprehension here is that CCS may be more expensive than that of wind or solar. However, as governments attempt to prop up the industry and help it achieve economies of scale, that will most likely change throughout this decade.

The last reason for the controversy surrounding CCS, and perhaps the one with the most potent emotional sticking point, is that CCS would essentially allow fossil fuel companies to maintain their

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[20] "Carbon Dioxide Capture and Sequestration: Overview." EPA, Environmental Protection Agency, 6 Jan. 2017, 19january2017snapshot.epa.gov/climatechange/carbon-dioxide-capture-and-sequestration-overview_.html.
[21] Rastelli, Eugenio, et al. "CO2 Leakage from Carbon Dioxide Capture and Storage (CCS) Systems Affects Organic Matter Cycling in Surface Marine Sediments." Science Direct, vol. 122, Dec. 2016, pp. 158–168. Marine Environmental Research, doi-org.proxy1.library.jhu.edu/10.1016/j.marenvres.2016.10.007., 166

status of power and influence within the American society. The reasons for why are essentially because they would be able continue to employ millions of Americans, maintain massive profits, and be able to corrupt/influence legislators at the federal and state level. Each of these reasons have been analyzed in grey literature. Gunderson, Ryan, Stuart, and Peterson in their piece *The Fossil Fuel Industry's Framing of CCS* state that fossil fuel companies "will support CCS because it can further and prolong profitability in the industry... by perhaps a few 100 years".[22] The reason for why this is possibly an extremely dangerous proposition is because these are the exact entities which successfully stymied and delayed bold climate action in America via a number of different ways. Brulle in his piece *Institutionalizing Delay*, connects the dots and shows how the climate change counter-movement "played a major role in confounding public understanding of climate science" as well as "successfully delay[ing] meaningful government policy actions to address the issue".[23] He also points out how a few major corporate funders of the fossil fuel industry bankrolled the movement. Therefore, the conclusion can be drawn that if these entities continue to maintain their positions of power and influence in American society, then perhaps a robust Green New Deal would fail to manifest itself in public policy at the federal level. Hence, wholeheartedly embracing CCS is an unwise and immoral philosophical approach because the corporate entities which stand to benefit the most from pervasive CCS utilization would continue to maintain their established societal power and influence, and thus they would have the capacity to effectively stymie efforts to implement a robust Green New Deal.

However, after having internalized all that about CCS technology and its role, perceived role, and its practicality, there is one saving grace to the technology, and that is its role in expanding the hydrogen

[22] Gunderson, Ryan, et al. "The Fossil Fuel Industry's Framing of Carbon Capture and Storage: Faith in Innovation, Value Instrumentalization, and Status Quo Maintenance." Science Direct, vol. 252, 10 Apr. 2020, pp. 1–9. Journal of Cleaner Production, www.sciencedirect.com/science/article/pii/S0959652619346372., 3

[23] Brulle, Robert J. "Institutionalizing Delay: Foundation Funding and the Creation of U.S. Climate Change Counter-Movement Organizations." Climatic Change, vol. 122, no. 4, 2013, pp. 681–694., doi:10.1007/s10584-013-1018-7., 682

industry. Hydrogen and its critical role in decarbonizing America will not be discussed in depth in this paper, but a quick primer on the subject is that hydrogen and fuel cells are essentially sustainable energies that have serious promise in allowing America to carry out a robust Green New Deal policy. The reason for why is because hydrogen can fill in a lot of the gaps in the economy that simply cannot be electrified, at least not yet. Examples of this are long range trucks, planes, ships, long-term baseload energy storage, and much more.

But this is where CCS comes into play, because creating hydrogen for use is an energy-intensive process. Of course, sources of that energy can come from renewable energy, or from other energy intense sources such as natural gas. And what is most required for the hydrogen industry to take off is for the production costs to be driven down via the principle of economics of scale. The Fuel Cell & Hydrogen Energy Association communicated this sentiment in their report, *Road Map to a US Hydrogen Economy*. This is a report intended for policymakers, business leaders, etc., and provides an in-depth analysis of the industry and what changes need to be made for hydrogen to play a more prominent role in the economy. But one of the key points in their "What needs to happen" section is that the relevant actors need to adopt "hydrogen across sectors [which] would lead to economies of scale and a decline in cost".[24] Therefore, a goal of climate activists, and anyone who wants a robust Green New Deal would want the hydrogen industry's costs to be driven down via economies of scale, and if there is a way to do that via a cost-effective and low-carbon or zero-carbon approach, then that would be a staple of a robust Green New Deal.

This is where CCS comes into play, and why it should be a necessary tool in the climate action toolbox. CCS is not only an opportunity for political compromise which can satisfy regions/communities reliant

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[24] Fuel Cell & Hydrogen Energy Association, 2020, Road Map to a US Hydrogen Economy, static1.squarespace.com/static/53ab1feee4b0bef0179a1563/t/5e7ca9d6c8fb3629d399fe0c/1585228263363/Road Map to a US Hydrogen Economy Full Report.pdf.79

upon fossil fuel utilization, it is not only a low-carbon way to deliver power to Americans in some parts of the country where renewables are impractical, but it can help the hydrogen energy industry achieve economies of scale extremely quickly. This idea is mentioned several times by the Fuel Cell & Hydrogen Energy Association's report, because wide-scale adoption of zero and "low-carbon hydrogen production methods [would help] ... achieve economies of scale".[25]

When internalizing everything surrounding nuclear energy and CCS, it is clear that wholeheartedly embracing, or rejecting both technologies is unethical and impractical. Both have roles to play in the years to come, but since they will be utilized in the American energy system, the consequences of their utilization must continue to be studied, and there must be a focus among policymakers, activists, etc., to mitigate their respective downsides and phase them out when it is time.

Urgency

The philosophy behind the desire for rapid mitigation efforts is something that must be understood. The reason for this is because the United States is the second largest emitter of greenhouse gas emissions, only behind China.[26] And, if too many GHGs are emitted, then capping global warming at 2 degrees C essentially becomes physically impossible. Therefore, the United States has an integral role in reducing the amount of GHGs emitted.

An article titled *Warming caused by cumulative carbon emissions toward the trillionth tonne* by Allen, Frame, et al., attempts to quantify how much GHGs may be emitted before 2 degrees C becomes unavoidable. It is important to quickly mention their concept of cumulative warming commitment

[25] Fuel Cell & Hydrogen Energy Association, 2020, Road Map to a US Hydrogen Economy, static1.squarespace.com/static/53ab1feee4b0bef0179a1563/t/5e7ca9d6c8fb3629d399fe0c/1585228263363/Road Map to a US Hydrogen Economy Full Report.pdf. 71
[26] Ge, Mengpin, and Johannes Friedrich. "4 Charts Explain Greenhouse Gas Emissions by Countries and Sectors." World Resources Institute, 5 May 2020, www.wri.org/blog/2020/02/greenhouse-gas-emissions-by-country-sector.

(CWC), which is the “peak warming response to a given total injection of CO_2 into the atmosphere”.[27] This is an important concept to internalize because if industrial emissions were to be immediately stopped, carbon-cycle feedback loops would continue to emit more CO_2 into the atmosphere. Therefore, after internalizing the concept of CWC, Allen, et al., concluded that the “value of the 1 Tt C CWC is 2^{o} C”.[28] Simply put they determined that the trillionth tone of CO_2 emissions would lead to, with a high degree of confidence, a 2^{o} C increase average on Earth.

This notion of surpassing the threshold is a paramount one because “many climatologists have argued that 450 parts per million is the absolute threshold”.[29] To put this into perspective, as stated earlier, before the industrial revolution CO_2 ppm was about 280 ppm, so civilization has added 133 ppm and only has about 37 ppm more to go before “risking dangerous anthropogenic interference with the climate system”.[30]

Lastly, whenever discussing urgency with respect to implementing a robust Green New Deal, positive feedback loops can neither be forgotten, nor understated. Positive feedback loops “enhance or amplify changes” which “tends to move a system away from its equilibrium state and make it more unstable”.[31] To better understand this notion, it is useful to perceive it within the context of positive feedback loops within the climate system. Perhaps the most obvious examples are wildfires. Wildfires annually have scorched vast swaths of land across the world. But they are key examples of a positive feedback loop because as they burn up trees (which store CO_2), carbon dioxide is released into the atmosphere, which

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[27] Allen, Myles R., et al. “Warming Caused by Cumulative Carbon Emissions towards the Trillionth Tonne.” Nature, vol. 458, no. 7242, 2009, pp. 1163–1166., doi:10.1038/nature08019., 1165
[28] Allen, Myles R., et al. “Warming Caused by Cumulative Carbon Emissions towards the Trillionth Tonne.” Nature, vol. 458, no. 7242, 2009, pp. 1163–1166., doi:10.1038/nature08019., 1165
[29] Brown, Marilyn A., and Michael Dworkin. “The Environmental Dimension of Energy Security.” The Routledge Handbook of Energy Security, doi:10.4324/9780203834602.ch8., 178
[30] Brown, Marilyn A., and Michael Dworkin. “The Environmental Dimension of Energy Security.” The Routledge Handbook of Energy Security, doi:10.4324/9780203834602.ch8., 178
[31] “Feedback Loops.” SERC Carleton, 19 Apr. 2020, serc.carleton.edu/introgeo/models/loops.html.

in turn increases the CO_2 ppm levels in the atmosphere, which leads to drier conditions for longer periods of time which creates more tinder for these fires.

Another marquee example of a positive feedback loop is the ocean albedo effect. Because of the physics of solar radiation and how it is either absorbed or reflected, the ocean (which is a dark color), absorbs much of that solar radiation and stores it which leads to a warmer ocean. However, when solar radiation hits light colored objects such as ice in the Arctic, it reflects off it and the ice does not absorb as much of that solar radiation as the ocean does. Yet the result is that as the ocean steadily becomes warmer, Arctic ice up against the ocean melts more quickly and/or breaks off from landmasses, and as the ice drifts off into the ocean it melts, leading to more water in the ocean which can absorb solar radiation, and less ice in the Arctic which can reflect it. The result of this is a positive feedback loop which exacerbates climate change.

Unfortunately, another devastating positive feedback loop must be mentioned, which is the thawing permafrost in the Arctic. In regions such as Siberia, unfathomably vast quantities of methane are stored underground. However, because of warmer temperatures in the region, the permafrost that has capped that methane is steadily thawing, releasing methane into the atmosphere. Methane is a much more potent GHG than that of CO_2 and absorbs about 84 times as much solar radiation than that of CO_2.[32] Therefore, this is an incredibly serious feedback loop. However, there is one recently discovered fact about the thawing permafrost which poses dire problems for civilization. An article by the Scientific American points out that "Arctic permafrost holds about 793 gigagrams of mercury – more than 15 million gallons," which is "nearly twice as much [mercury] as all the other soils, the ocean and the

[32] "The Challenge." UNECE, www.unece.org/energywelcome/areas-of-work/methane-management/the-challenge.html.

atmosphere combined".[33] This is a major problem because this mercury would "circulate through the global marine system or escape into the atmosphere and travel to other parts of the planet".[34] There is no telling for sure where it would go, but scientists are certain of is that it'd have extremely serious consequences and that "it's definitely something to be worried about".[35]

METHODS: THE PHYSICS AND POLICY

Now that the philosophical approach to implementing a robust Green New Deal has been established, it is time to calculate how much clean and renewable energy needs to be deployed and how much it will cost. The reason for deciding to calculate the cost of a net zero carbon emissions electric grid is because this is most attainable climate action goal within the next 10-20 years in America, and it is a commonly understood notion which, simply put, is "let's build enough solar panels and wind turbines so that we don't need to burn coal and natural gas." Of course, that is an oversimplification of the issue, and while a robust Green New Deal would have to account for a net zero carbon emissions economy which includes agriculture, industry, and transportation, the first step to achieving a robust Green New Deal is to establish a zero carbon emissions electric grid. This achievement is foreseeable and is a goal for President-Elect Joe Biden.

On the campaign trail, President-Elect Joe Biden committed to attaining a zero carbon emissions electric grid by 2035 by proposing to "make a federal investment of $1.7 trillion over the next ten years,

[33] Sneed, Annie. "The Arctic Permafrost Holds a Crazy Amount of Mercury-and That's Bad News." Scientific American, Scientific American, 9 Feb. 2018, www.scientificamerican.com/article/the-arctic-permafrost-holds-a-crazy-amount-of-mercury-mdash-and-thats-bad-news/.
[34] Sneed, Annie. "The Arctic Permafrost Holds a Crazy Amount of Mercury-and That's Bad News." Scientific American, Scientific American, 9 Feb. 2018, www.scientificamerican.com/article/the-arctic-permafrost-holds-a-crazy-amount-of-mercury-mdash-and-thats-bad-news/."
[35] Sneed, Annie. "The Arctic Permafrost Holds a Crazy Amount of Mercury-and That's Bad News." Scientific American, Scientific American, 9 Feb. 2018, www.scientificamerican.com/article/the-arctic-permafrost-holds-a-crazy-amount-of-mercury-mdash-and-thats-bad-news/.

leveraging additional private sector and state and local investments to total to more than $5 trillion".[36] In order to decipher whether these figures are accurate, I decided to calculate the cost of a zero carbon emissions electric grid myself.

For the sake of simplicity, I analyzed five different states, each with different energy portfolios. The reason for calculating states with different energy portfolios is because there is a plethora of available energy in each of the 50 states, and many different types of energy. Everything from offshore wind, to solar, to geothermal, to wave kinetic energy is available for powering the country.

To calculate how much it will cost to have a net zero emissions electric grid, I will calculate how much clean and renewable energy (in MWh) will need to be developed, and how much that will cost over the next couple of decades, using these five states as case studies: Kansas, Massachusetts, Pennsylvania, Oregon, and California. The reason for analyzing these five states are as follows:

- Kansas is 2nd in the nation in utilizing wind energy to power in-state electricity (41.4%), and 49% of its electricity comes from clean sources.[37]
- Massachusetts is 1st in the nation in offshore wind energy potential (239,855 MW) and has 87.4% of its electricity from fossil fuels. [38][39]
- Pennsylvania powers its electricity with 69% of its electricity with fossil fuels, 28% from nuclear, and has relatively little renewable energy potential.[40]
- Oregon powers its electricity with 71% of renewables, with 53% from hydroelectric.[41]

[36] "Plan for Climate Change and Environmental Justice: Joe Biden." Joe Biden for President: Official Campaign Website, 29 Oct. 2020, joebiden.com/climate-plan/.
[37] "State Facts Sheets." AWEA, www.awea.org/resources/fact-sheets/state-facts-sheets.
[38] "State Facts Sheets." AWEA, www.awea.org/resources/fact-sheets/state-facts-sheets.
[39] "U.S. Energy Information Administration - EIA - Independent Statistics and Analysis." Homepage - U.S. Energy Information Administration (EIA), www.eia.gov/state/seds/.
[40] "U.S. Energy Information Administration - EIA - Independent Statistics and Analysis." Homepage - U.S. Energy Information Administration (EIA), www.eia.gov/state/seds/.
[41] "U.S. Energy Information Administration - EIA - Independent Statistics and Analysis." Homepage - U.S. Energy Information Administration (EIA), www.eia.gov/state/seds/.

- California powers its electricity with 54% of clean energy, with 6.5% from nuclear, 14% from hydroelectric, and 33% from renewables.[42]

As stated earlier, these five states were chosen because they each have different energy portfolios. Kansas is #1 in the nation in land-based wind energy potential per square mile. Massachusetts is #1 in the nation in offshore wind energy, which means that it is #1 in a cutting-edge energy technology, which could provide insight for states which could benefit from future energy technologies like OTEC. Pennsylvania has little energy potential and will be forced to rely on fossil fuels and nuclear, which means that CCS and allowing nuclear reactors to stay operational will be key to helping Pennsylvania attain net zero emissions. Also, Pennsylvania is unique in the sense that it is the nation's "largest net exporter of electricity," which could provide a roadmap for exporting renewable energy electricity from renewable rich regions in the country (i.e., Kansas or Massachusetts).[43] Oregon has the most clean energy within its portfolio of the five listed states, because of hydroelectric dams. And California, which has the largest energy demand of the five, is quite clean with a diverse array of energy options within its portfolio, yet it is "the largest net importer" of electricity.[44] These numbers were taken from studies in 2018 and 2019 and may not be the most up to date numbers possible.

Before moving forward, this model should be cross referenced with the country's energy system to verify how accurate it really is. The average utilization of fossil fuels in these states' electric grids is 56.5%.

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[42] "U.S. Energy Information Administration - EIA - Independent Statistics and Analysis." Homepage - U.S. Energy Information Administration (EIA), www.eia.gov/state/seds/.
[43] "U.S. Energy Information Administration - EIA - Independent Statistics and Analysis." California Imports the Most Electricity from Other States; Pennsylvania Exports the Most - Today in Energy - U.S. Energy Information Administration (EIA), www.eia.gov/todayinenergy/detail.php?id=38912.
[44] "U.S. Energy Information Administration - EIA - Independent Statistics and Analysis." California Imports the Most Electricity from Other States; Pennsylvania Exports the Most - Today in Energy - U.S. Energy Information Administration (EIA), www.eia.gov/todayinenergy/detail.php?id=38912.

Average utilization of fossil fuels:
KS = 51%, MA = 87%, PA = 69%, OR = 29%, CA = 46%

Therefore, because the average fossil fuel percentage is 56.5, and the national average listed by the EIA is 62.6%, we can conclude that this model is quite reflective of the energy portfolio of the country, thus the following variables will be applicable.[45]

So how much will it cost for each of these states to attain net zero emissions? To calculate this, five variables will be factored in:

- Average energy demand increase
- Average dirty energy % of the states
- Average LCOE of RE
- Projected CCS LCOE by 2030
- R&D factor

Let me explain each of these variables.

- Average electricity demand increase: This variable simply determines what the electricity demand will be in 2030, 2040, etc. If a Green New Deal is going to deliver a net zero emissions electricity sector, it must account for the continually increasing electricity demand of the country. However, it should be noted that there is ambiguity here as well since the transportation sector's energy demand will steadily bleed into the electricity demand due to electric vehicles (EVs). Transit vs EVs will be discussed later in this section.

[45] "What Is U.S. Electricity Generation by Energy Source?" Frequently Asked Questions (FAQs) - U.S. Energy Information Administration (EIA), www.eia.gov/tools/faqs/faq.php?id=427&t=3.

- The average annual electricity demand increase has been a steady 1%.[46]
- This leads to this formula which would project the compounding electricity demand over a decade:
  - Electricity demand * $(1+.01)^{10}$
  - ***$D*(1+.01)^{10}$***

- Average fossil fuel energy % of the states: This case study establishes a representative model of the country's energy system by calculating the average percentage of fossil fuels utilized for a state's electricity portfolio, thus, how much energy needs to be decarbonized.
  - ***FF***
- Average RELCOE (renewable energy levelized cost of energy): once the total percentage of energy which needs to be decarbonized is calculated, if renewable energy is going to take its place, an average of the levelized cost of renewable energy is determined. Simply put, if 100 MWh needs to be decarbonized, and the average LCOE of RE is $50/MWh, then it would cost $5,000 to decarbonize that dirty energy demand.
  - ***RE***
- Projected CCS LCOE by 2030: this is one of the more ambiguous variables. This technology is still very new, and there is no clear average LCOE within the USA. That ambiguity will be discussed more in depth later in this section.
  - ***CCS***
- R&D Factor/efficiency: This is the most difficult number to project. There is a wide range of possibilities with research and development. If there is an unforeseen technological breakthrough, the cost of energy could plummet. If a modern electric grid were to be

[46] "Annual Energy Outlook 2019 - U.S. Energy Information ..." Annual Energy Outlook 2019 with Projections to 2050, U.S. Energy Information Administration, 24 Jan. 2019, www.eia.gov/outlooks/aeo/pdf/aeo2019.pdf., 90

developed, that would increase the efficiency of the grid and mitigate transmission losses. Or, not much, relatively speaking, could change over the next decade or two. Therefore, the number provided, 85% is a rough estimate based on purely my sense of the topic. This is the greatest wildcard in these cost projections, and the "wildcard factor" will be addressed at the end of this section.

- ***X***

Below is the equation:

The Cost to Decarbonize the American Electric Grid by 2030 = D * (1+.01)^{10} * FF * (RE * CCS)/2 * X

Note, *The Cost to Decarbonize the American Electric Grid* is the total cost to society. The vast majority of this will be paid by renewable energy companies, municipalities, citizens who want to generate energy via programs like residential solar, and other entities. However, the government/taxpayers will pay for a portion of this total cost, and that must be calculated. To do that, the total cost of tax credits must be calculated.

First, the LCOE for these technologies throughout the next two decades must be calculated/projected. With respect to the LCOE for these technologies, it is important to mention that these are estimates, and that there is no hard number out there. The most accurate estimations available are from the EIA in their *Annual Energy Report*.[47]

- Wind, land-based: Total LCOE including tax credit = $35.97/MWh.
- Wind, offshore: Total LCOE including tax credit = $85.53/MWh.
- Solar photovoltaic: Total LCOE including tax credit = $27.71/MWh.

[47] "Annual Energy Outlook 2019 - U.S. Energy Information ..." Annual Energy Outlook 2019 with Projections to 2050, U.S. Energy Information Administration, 24 Jan. 2019, www.eia.gov/outlooks/aeo/pdf/aeo2019.pdf., 19

- Hydroelectric: Total LCOE including tax credit = $53.58/MWh.

The referenced EIA report provides the average of RELCOE for 2025. The estimation for the 2020-2040 RELCOE will also be derived from the EIA report, but via finding the average between the 2025 LCOE projection, and the 2040 LCOE projection. While this would yield the average LCOE projection for 2032 and 6 months, it is close enough to 2030 so that it is a reasonable estimation.

Aside from the R&D variable, the other one with the most uncertainty is the LCOE of CCS. CCS is a technology that has yet to be deployed in the United States and is hardly deployed anywhere else in the world. There is also sparse grey literature on the subject, with a wide range of the LCOE for the technology. A journal article from MDPI states that the LCOE for CCS could be as low as $26/MWh.[48] They came to this conclusion under the assumption of "significant economies of scale".[49] However, an Elsevier *International Journal of Greenhouse Gas Control* article came to the conclusion, based on the calculations from multiple entities including the Department of Energy, International Energy Administration, and the Electric power Research Institute, that the current average estimated current LCOE for CCS is $112.7/MWh (Int. J. Greenhouse Gas Control, Rub, E.S., et al., 17).[50]

Therefore, it is extremely hard to know what the true projected LCOE for CCS is in the decade of 2020, and further estimations must be made within this equation. The estimation that will be made is to split the difference and find the average between $112.7/MWh and $26/MWH. That number is $69.35/MWh, and this is a fair assumption for one primary reason, which is that CCS is/will be a priority for the United States government, and the industry will be subsidized and promoted with tax credits and

[48] Lee, Bong Jae, et al. "Economic Evaluation of Carbon Capture and Utilization Applying the Technology of Mineral Carbonation at Coal-Fired Power Plant." Sustainability, vol. 12, no. 15, 2020, p. 6175., doi:10.3390/su12156175., 26
[49] Lee, Bong Jae, et al. "Economic Evaluation of Carbon Capture and Utilization Applying the Technology of Mineral Carbonation at Coal-Fired Power Plant." Sustainability, vol. 12, no. 15, 2020, p. 6175., doi:10.3390/su12156175., 8
[50] Rubin, Edward S., et al. "The Cost of CO2 Capture and Storage." International Journal of Greenhouse Gas Control, Elsevier, 3 July 2015, www.sciencedirect.com/science/article/pii/S1750583615001814?via=ihub., 17

R&D investment. Evidence of that is that in September of 2020, the House of Representatives passed H.R. 4447 – Clean Economy Jobs and Innovation Act, which included sections intended to expand the CCS. Specifically, § 962 includes a "program of research, development, demonstration, and commercial application of carbon capture technologies, which shall include facilitation of the development and use of" technologies including CCS.[51]

Of course, $69.35/MWh may be too low, or too high, but it is an estimate which leads to a solid equation which can project the cost of a zero carbon emissions electric grid. And, for good measure, in the equation for the 2040 projections, the LCOE of CCS will be $66.83/MWh because the average projected ***RE*** in 2030 is $2.52/MWh greater than it is in 2040. Yet, more research must be done on this matter, <u>and once a more concrete LCOE of CCS becomes apparent, that number should be added into this equation to find out how much a zero emissions electric grid will cost.</u>

Once we scale this equation to the whole nation, we can see how much money it will cost the society to make the electricity sector fully clean. In 2019, the USA's electricity generation was 4.118 billion MWh.[52]

Average Tax Credit Cost

- Solar tax credit (ITC) is 30% in 2019, 26% in 2020, 22% in 2021, 5% in 2022 (10% for utility scale, 0% for residential).[53]
- Wind energy tax credit (PTC) was $15/MWh.[54]

To calculate how much the federal government will pay for establishing a zero carbon emissions electric grid, the average cost of clean energy tax credits must be determined. This will be another estimation

[51] United States, Congress, *Clean Economy Jobs and Innovation Act*. 2019, p. 1206
[52] Total Energy Annual Data - U.S. Energy Information Administration (EIA), www.eia.gov/totalenergy/data/annual/.
[53] "Solar Investment Tax Credit (ITC)." SEIA, www.seia.org/initiatives/solar-investment-tax-credit-itc.
[54] Power, America's. "It's Time to End Subsidies for Renewable Energy." America Power, 26 May 2020, www.americaspower.org/its-time-to-end-subsidies-for-renewable-energy/#_ednref1.

for a handful of reasons. First, the tax credits are subject to Congress, and it is possible that Congress continues to extend these tax credits, and it is also possible that Congress lets them expire. However, the assumption will be made that Congress will continue to extend them as Congress has done for over a decade. As of now, the solar investment tax credit is 22% (in 2020) and the wind production tax credit is \$15/MWh. However, it should be noted that the solar ITC is set to expire. Yet, there are further complications since entities like trade associations continually lobby Congress to extend these tax credits. Therefore, it is difficult to project the tax credit which will be provided to the solar energy industry. This topic will be covered more in depth in the politics section, but the analysis pulled from that section leads to the assumption that the solar ITC will be extended to be 20%, on average, throughout this decade. And, for the sake of simplicity, the average will be calculated between solar and wind, to find out how many \$/MWh the federal government will supply. This number will determine basically a "renewable energy tax credit" and will shed light on the cost projection for reaching a net zero electric grid.

\$11.6/MWh is the average "renewable energy tax credit" (RETC).

(See Appendix B)

17.32% of the cost is paid for by the government

G = 17.32%

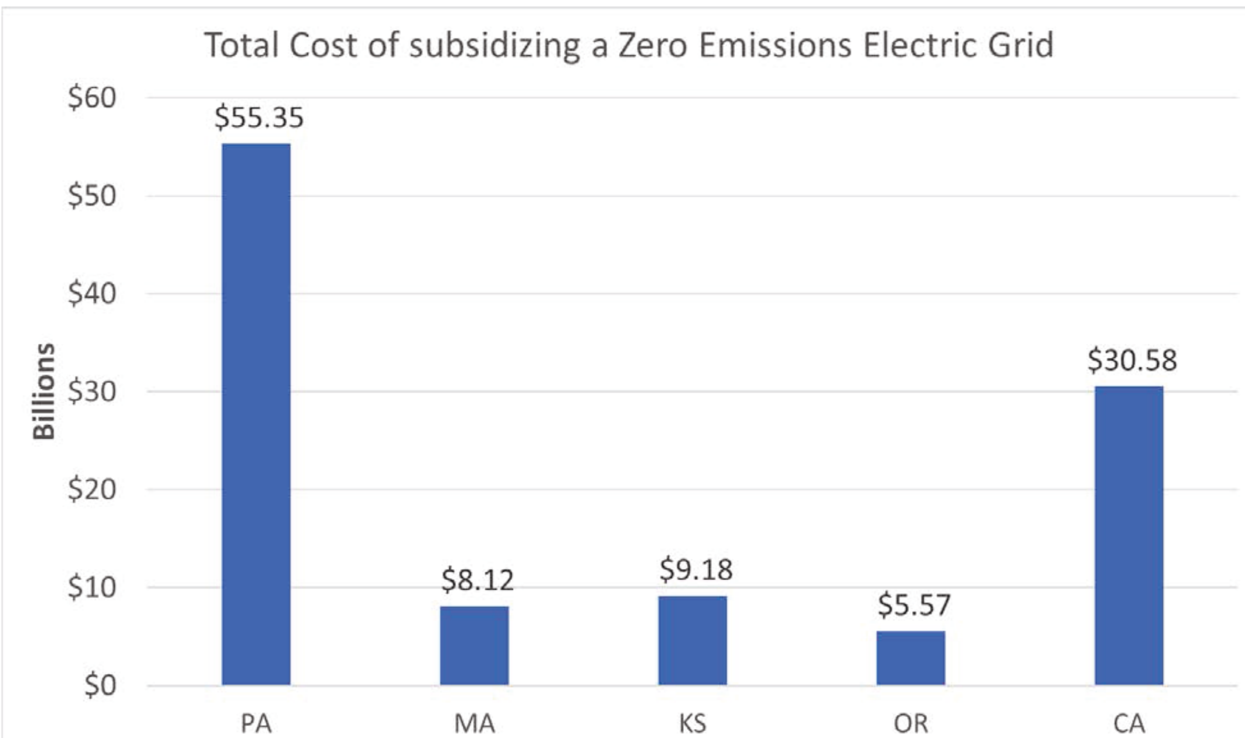
(See Appendix B)

One final note with respect to this cost, is that the cost of subsidizing CCS will be negated. The reason for doing so is because the projected LCOE of CCS is very close to that of the RELCOE. For this reason, it is fair to assume that CCS will be subsidized at a similar rate (if not identical rate) to that of renewable energy. For this reason, the 17.32% value may remain unchanged when applied below.

Now that the RETC for the decade of 2020 has been estimated, it is time to apply this to the case model states and see how much money the government will be subsidizing renewable energy proliferation.

The Cost to Decarbonize the American Electric Grid * G = →
The Cost to Decarbonize the American Electric Grid for the Federal Government

After establishing these calculations and the formula, if these tax credits were to be extended thru to 2030, and if the goal were to have a net zero emissions electric grid in those five states, the total cost in each of the five states are:



(See Appendix A)

Before applying these calculations to the rest of the country, some observations should be noted. Unsurprisingly Oregon, the state with the highest percentage of clean energy, requires the least amount of money to reach a net zero electric grid. It may surprise some that the money required to do so is about just $5.6 billion. It also may surprise some that the state which costs the most to reach net zero is Pennsylvania, and not California. The reason for why is because Pennsylvania exports a lot of electricity via natural gas fired power plants and transmission to other states. This goes back to the earlier point as to why Pennsylvania is a good case study because states like Massachusetts, New York, or Arizona, those with extremely promising renewable energy (offshore wind and solar) potential, may be inclined to export that electricity to neighboring states.

Before scaling these calculations to the rest of the nation, including projections for the goal of 2040 decarbonization, another key facet of American energy must be accounted for: transportation.

Transportation

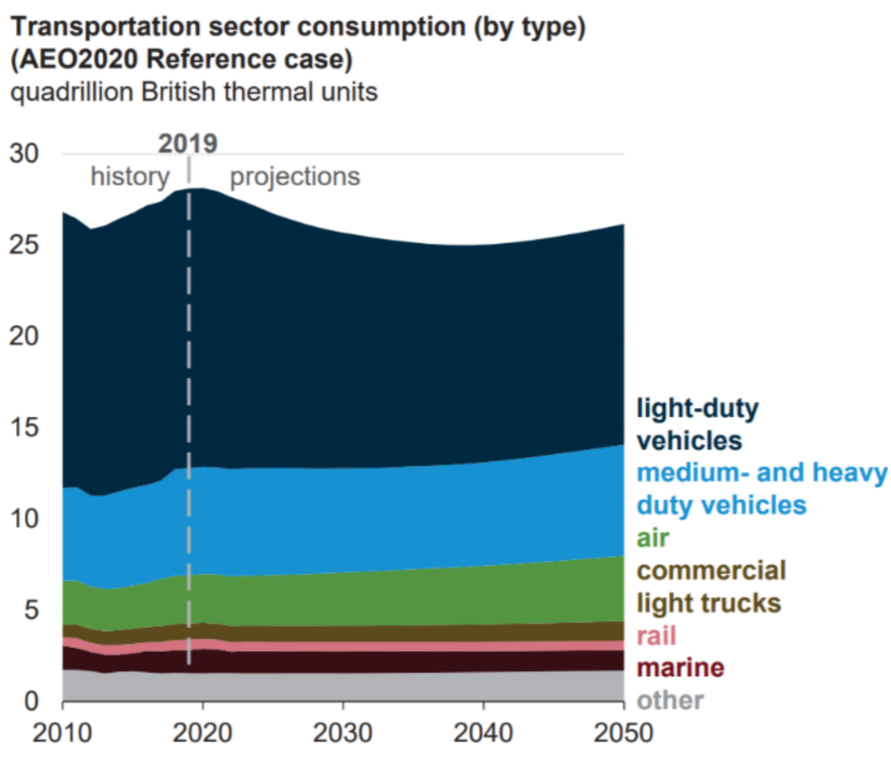


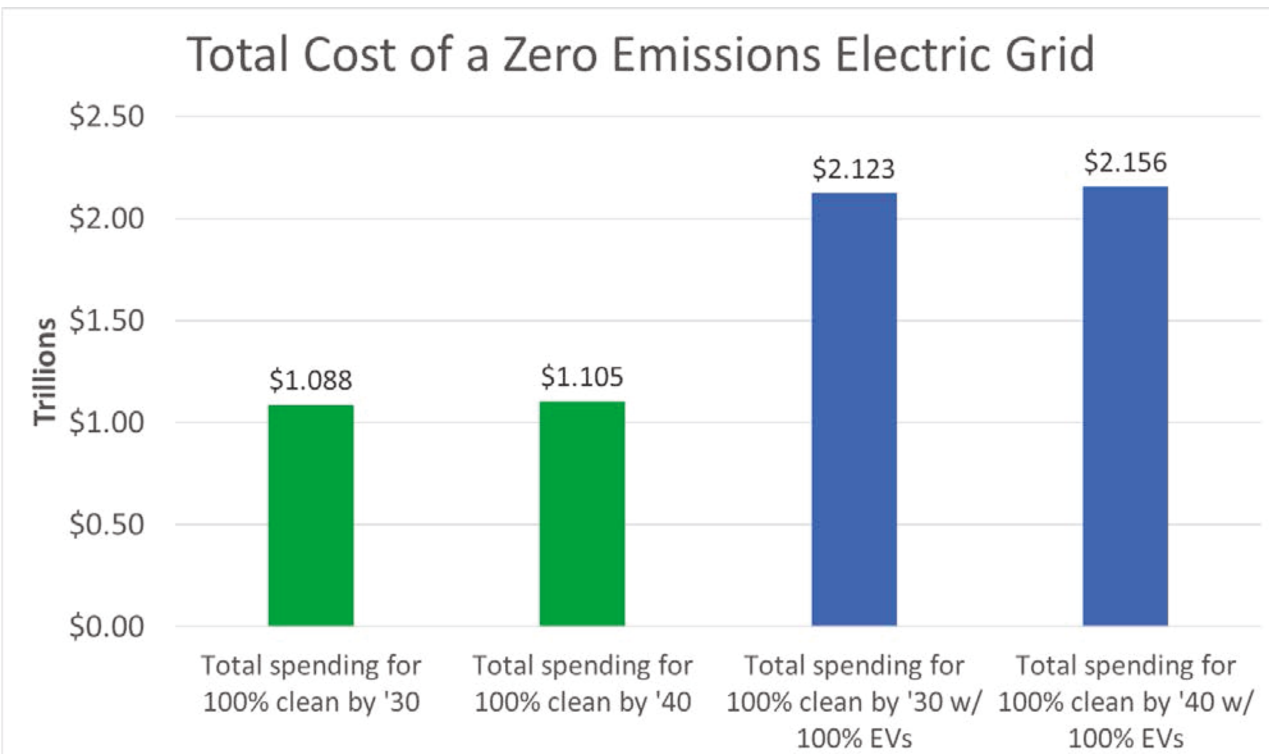
Figure 2: Transportation sector consumption by type[55]

[55] "Annual Energy Outlook 2019 - U.S. Energy Information ..." Annual Energy Outlook 2019 with Projections to 2050, U.S. Energy Information Administration, 24 Jan. 2019, www.eia.gov/outlooks/aeo/pdf/aeo2019.pdf., 117

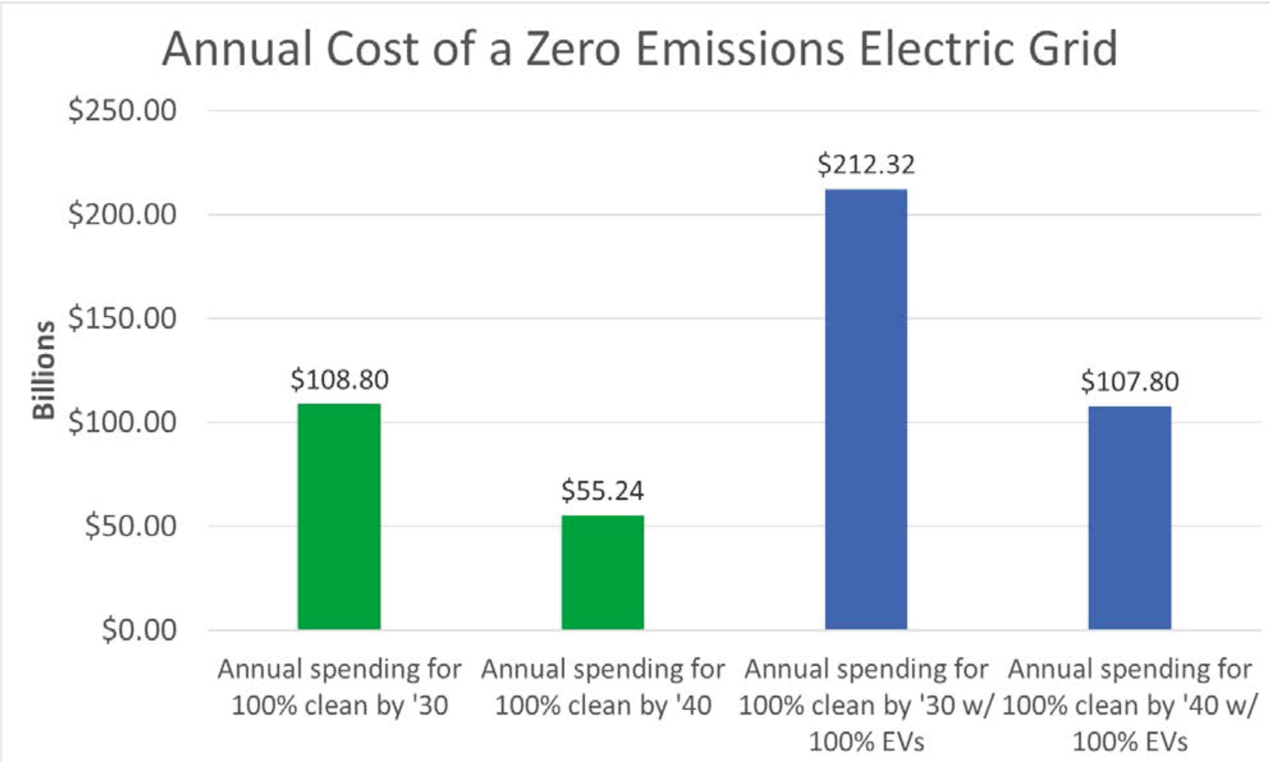
This image from the EIA illustrates vehicles' distribution within the transportation sector.[56] It illustrates the fact that from 2020-2030, about 26 trillion BTUs will be used in the transportation industry annually. Converting that to MWh, that is about 7.327 million MWh annually *(See Appendix B).*

And, if light-duty vehicles, medium-and heavy-duty vehicles, and commercial trucks account for about 13+7+1 = 21 trillion BTUs (21/26 = 81%) of that industry, then EVs would have to account for 5.918 million MWh annually in this decade.

The Costs of a Zero Emissions Electric Grid with Different Scenarios



[56] "U.S. Energy Information Administration - EIA - Independent Statistics and Analysis." Annual Energy Outlook 2020 with Projections to 2050



(See appendix A)

From these calculations, four observations are apparent.

1. These values of simply maintaining the established anticipated level of incentives for clean energy industries, the President-Elect's proposed value of essentially about $1-$2 trillion spending to attain a clean energy electric grid by 2035 seems to be accurate.
2. On an annual basis, the cost for a net zero emissions electric grid is relatively small. If the United States wanted to have a net zero emission electric grid by 2030, it would only cost about $120 billion annually. And if the United States wanted to have a net zero emissions grid by 2040, it would only cost about $59 billion annually. The reason for claiming that this is "relatively small" will be addressed in the discussion section.
3. The cost differential of aiming to have a net zero emissions grid by 2030 versus 2040 is not much at all. The reason for this is because the projected RELCOE and CCS LCOE do not seem

to dramatically drop anytime soon. While this is still a feasible possibility and factored into the *X* variable, there is not much of a valid argument to decide to wait until 2040 because of a decreasing LCOE. However, there is an argument to be made that if the federal government's deficit is too high, because on an annual basis the federal government would only be paying about half of that cost ($58 billion versus $120 billion).

4. The costs of a net zero emissions electric grid practically double if the United States were to totally rely on EVs for decarbonizing its transportation industry.

So, in order to keep the costs down of developing a zero carbon emissions electric grid, energy solutions for the transportation industry must be analyzed.

Transit's Role in decreasing the cost of a Zero Carbon Emissions Electric Grid

To decrease the cost for a zero carbon emissions electric grid, low-energy transit solutions must be deployed. Fortunately, all throughout the world, as well as some areas in the United States, low energy solutions such as subways, trains, light-rail etc., exist and have demonstrated their abilities to transport people from point A to point B while requiring much less energy than that of an automobile.

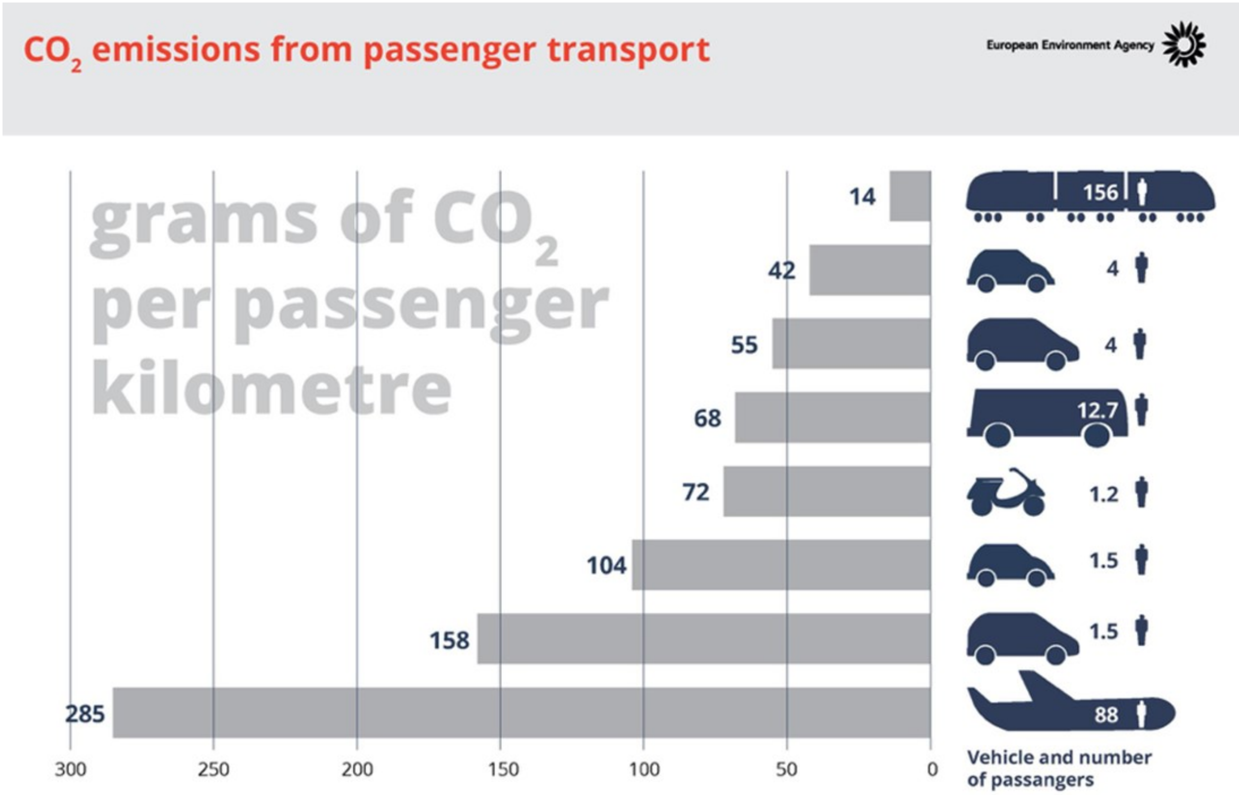


Figure 3: CO2 Emissions from Passenger Transport (European Environment Agency)[57]

As evidenced by the figure above, different modes of transportation require different amounts of energy. Of course, the most energy intense mode of transportation is flight, and the least intense is train/subway/light rail. The reason for this is has to do with the physics of transportation, and how much energy it takes to move an object forward and through air. For this reason, cars require about 10x more energy than that of an electrified transit mode. Of course, it is not exactly 10x, but for the sake of these calculations, it is close enough to make an accurate estimation as to how much the energy disparity is, and how much this may cost if the transportation sector in America were to be revamped.

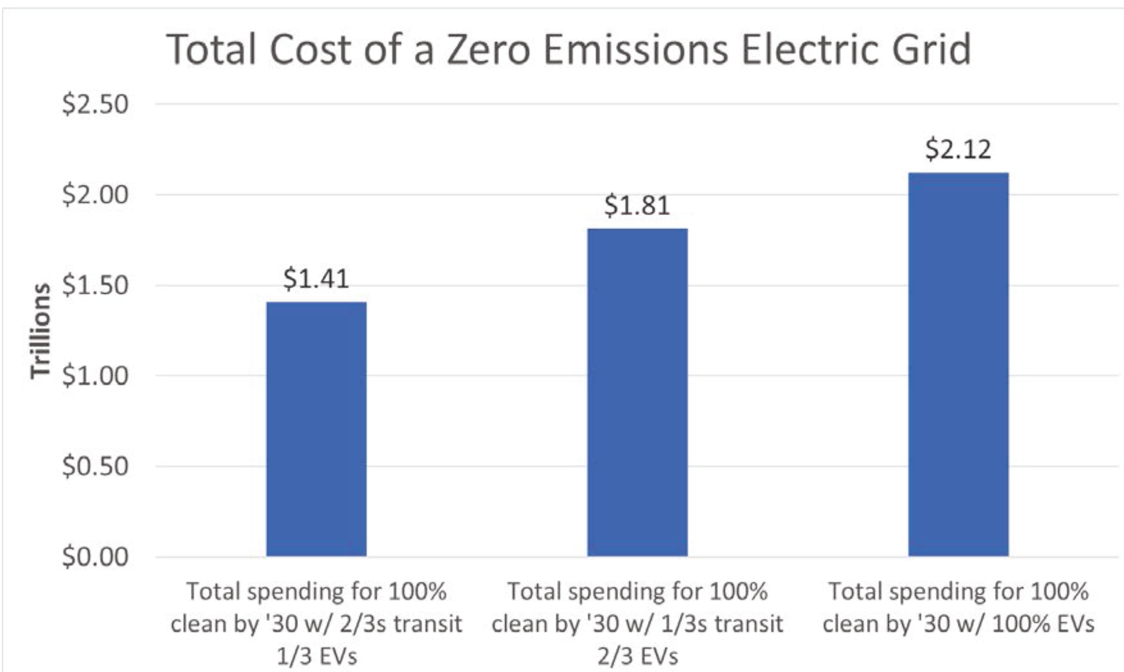
An important note before discussing the costs of a transit system, much of transit relies on urban planning, and how a metropolitan area is laid out. Thus, cities that are smaller lend themselves better to

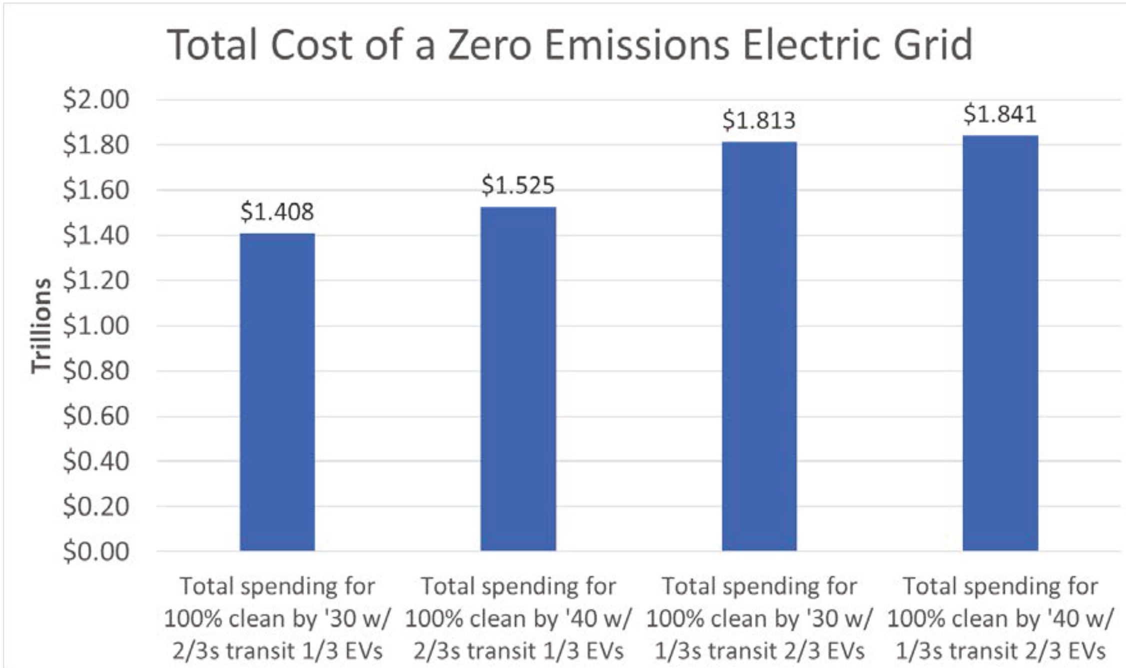
[57] "Transport." European Environment Agency, 8 Mar. 2019, www.eea.europa.eu/themes/transport.

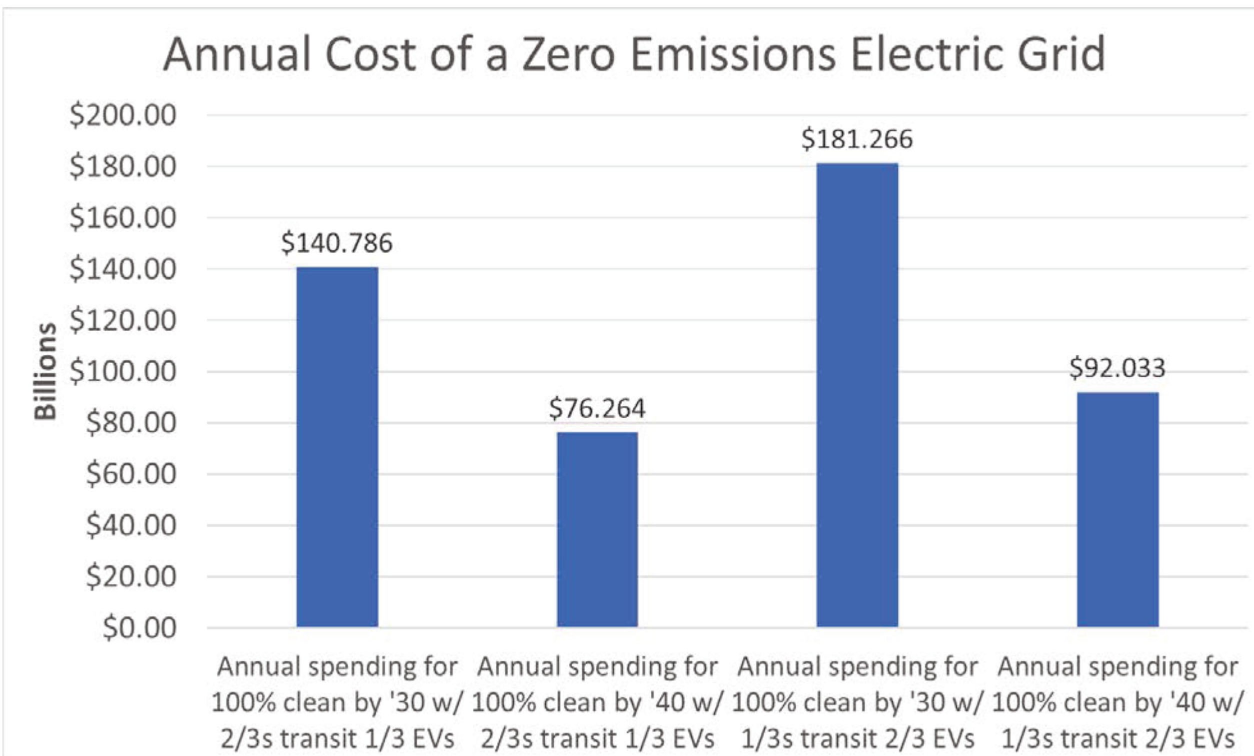
transit solutions like subways and light rail. This is important to note because if the American transit system were to be revamped across its many metropolitan areas, it is suspected that cities would be redesigned such that transportation modes are not required to take people as far as it used to. Simply put, if getting someone from point A to point B in the average American city in 2020 is 10 miles, due to climate change and energy conservation efforts by municipalities, that point A to point B in 2040 may be 5 miles. Because of that fact, these calculations may be off to a degree, but that is a variable which is incredibly difficult to project/account for.

Now that the role of transit within a robust Green New Deal has been established, it is time to calculate and view the range of costs for a robust Green New Deal.

RESULTS: THE TRUE COSTS







(See Appendix A)

DISCUSSION

Why Transit Development is a Better investment than Relying on EVs

The most obvious and anticipated result from these calculations is that the cost of a zero carbon emissions electric grid decreases substantially if electrified transit is deployed.

For this reason, electrified transit should be an integral part of a robust Green New Deal, because it would save money by requiring less clean energy deployment across the nation, and it would save energy because the transportation sector would increase at a much slower rate than if EVs were to totally replace automobiles. However, it should be noted that transit options can take a long time to be developed, they require a lot of planning on behalf of government entities, and they require a lot of financing. Yet in the medium run and long run, it is clear from these graphs that electrified transit is the favorable choice because once it is developed in the right areas, far less money would need to be spent by citizens who would need to buy EVs, hence saving them money because they wouldn't have to take out loans, find the cash for down payments, etc., and far less money would need to be spent by the entities like the government in order to deploy clean energy technologies. There is also the benefit of America having a smaller ecological footprint by utilizing less lithium ion, steel, etc. for EVs, but the broad subject of ecological overreach will not be delved into in this paper.

There are other reasons which can be economically calculated but have more of an intrinsic value. For example, there would be less accidents and fatalities from car accidents. While safety features in cars have become much more commonplace, and autonomous vehicles are an inevitability, it is unknown when automobile-related accidents and fatalities would have a probability lower than that of transit. Transit would also lead to less congestion in streets and allow cities to embody a different atmosphere. For example, outdoor dining, which New York has successfully employed in the post-COVID era, has taken advantage of the space which streets provide.[58] If there are less cars on the road or no cars on the road within a specific region within a city, there is room for more commerce and entertainment avenues. These are not the only benefits of less congestion within a city, but these examples are to provide you with the perspective of the potential and possibilities which investing in transit and shifting away from EVs/cars would provide people, businesses, municipalities, and the country.

If this were a different paper, which focused more in depth on the cost differentials between transit and EVs, a more comprehensive argument would be laid out. But I felt as though it was important to briefly address this issue, considering how integral it is in terms of calculated the cost of a zero carbon emissions electric grid.

Uncertainty

To round out the methods section, several caveats must be noted. The first is that there is still great uncertainty with respect to the nation's electricity demand, and electricity portfolio going forward. While the projections from the EIA seem accurate, they may be inaccurate due to an unforeseeable event. One example of that is if a climate hawk were to be elected president in 2024, and they would be able to influence American electricity demand patterns such that these calculations are rendered inaccurate. A way of thinking about this is that if the climate hawk president were able to convince the American people, via inspiration or policy, to use 10-20% less electricity, that could seriously change these calculations. Also, within the realm of uncertainty, there could be technological breakthroughs with respect to energy technologies. Advanced nuclear, OTEC, biomass, geothermal, solar thermal, or another unforeseen technology such as unexplained aerial phenomena, could become much more

[58] Petersen, Camille. "NYC Restaurants Spill Out Onto The Asphalt To Stay In Business." NPR, NPR, 18 Aug. 2020, www.npr.org/sections/coronavirus-live-updates/2020/08/18/901993301/nyc-restaurants-spill-out-onto-the-asphalt-to-stay-in-business.

practical and cost competitive. This would change these calculations because the variable, ***RELCOE*** could plummet in a relatively short period of time.

Lastly, it is important to mention that these calculations are more or less "back of the napkin" calculations. That is, in the sense, there are many rough estimations made to come up with a proper number. The ***X***, ***G***, and ***CCS*** variables are all estimations, for simple reason that it is literally impossible to project what they will be throughout this decade.

Policy Recommendations

- Extend clean energy production and investment tax credits through 2030 and/or 2040. This would continue to make these technologies more competitive in the marketplace.
- Make developing electrified transit a focal point of a Green New Deal. This would decrease the cost of a net zero carbon electric grid and save consumers money since they will not need to pay for EVs.
- Enact a national RPS, CES, or carbon tax. This would make clean energy technologies more competitive in the marketplace. A national RPS or CES is more likely to implement than a carbon tax given the state of the senate.
- Continue to fund R&D efforts. Physics favors technologies like OTEC and solar thermal, but those industries need more incentives to get off the ground. This would minimize ***X.***
- Upgrade transmission. This would be the greatest national energy efficiency project possible, and would also minimize ***X***.
- Subsidize or totally pay for education to learn the relevant skills. Workers learn the skills to work in the solar and wind industries at community and technical colleges, and retraining programs. This would provide the industry the needed labor supply to proliferate these technologies and accelerate the process.

Politics Going Forward

The ultimate barrier to getting a robust Green New Deal through Congress is the politics of America. At the end of 2020, America's political situation is one of division, which is accurately reflected in the incoming 117th Congress. The President-Elect is a Democrat, the Democratic party will control the House, and senate races have yet to finish. These senate races are in Georgia and will be decided in early January. The outcome of those two races will determine the senate's makeup in the 117th Congress, and it is unclear what the result will be given that neither candidate is polling well enough to win handily. Therefore, the senate may be split 50-50, or the Republicans will control the senate.

This is important to internalize because if the senate is split 50-50, the probability of a robust Green New Deal being signed into law becomes more likely. The reason for this assertion is given the favorability of a Green New Deal within the Democratic party, and the animosity towards that notion within the Republican party. Another reason is the fact that the President-Elect has hinted that he would be more willing to compromise with a Republican controlled senate on a stimulus package. While the House of Representatives in the Fall passed a stimulus bill of over $3 trillion, and President-Elect Biden has indicated that he would move “toward Mr. McConnell’s offer of a $500 billion package”.[59] This is important to remember in the event that if/when a climate bill were to begin making its way through Congress, Mr. Biden could attempt to persuade leaders in Congress to scale down the bill, and make it less ambitious, in an effort to compromise with the Republicans who still control the senate. If that were to be the case, a 2040 zero carbon emissions electric grid would be more likely than a 2030 goal, and the same applies to Mr. Biden’s proposed 2035 plan. The reason for this, as calculated above, is that the plan would cost about 50% less annually if the goal were 2040. However, if the senate were to be split

[59] Tankersley, Jim, and Emily Cochrane. “Biden Team, Pushing Quick Stimulus Deal, Prepares for Renewed Recession.” The New York Times, The New York Times, 22 Nov. 2020, www.nytimes.com/2020/11/22/business/economy/biden-coronavirus-stimulus-recession.html.

50-50, and the Vice-President Elect Harris could be a pivotal tie-breaker vote, a more ambitious climate plan to attain a zero carbon emissions electric grid in 10-15 years becomes more likely.

However, either way, something that should not be forgotten is that if Democrats and Republicans want less spending in the medium and long run, electrified transit must be embraced to mitigate the demand increase for electric transportation.

Messaging

Perhaps the most compelling argument against spending on a robust Green New Deal is that the federal government will be unable to afford this degree of spending, and that the deficit is too high. However, this argument depending on the person/people articulating it may be in bad faith and not borne out of the country's economic reality.

Two scenarios must be foreseen before attempting to pass a bill which would attain a zero carbon emissions electric grid. The first scenario is one of total opposition to extra spending which would add to the deficit. In this scenario, any proposal to spend between an extra $76 billion to $182 billion would be preposterous to many Members of Congress. While renewable energy tax credits are still part of the federal budget for the next few years, let’s set that argument aside to strike at the core of what the messaging should be. If that spending increase is proposed, it is reasonable to believe that the opposing Members will oppose such legislation because *the country simply cannot afford that spending increase*. The response to this assertion should be one which relates to three different moments in history, 2017-2020 (Trump tax cut), the 2020 Pandemic, and the 1930s-1940s.

The Trump tax cut should be the first line of response towards Members who oppose this spending increase, and the reason for why is because it is reasonable to assume that the deficit hawks (the ones opposing deficit increases) will be the Republicans. The reason for this assertion is because they were the ones who opposed deficit increases during Obama’s term, therefore it is reasonable to assume that they would do the same during a Biden presidency. Also, it was the same party which supported the Trump tax cut which dramatically increased the deficit. The explanation for why the Trump tax cut according to them was that it was a necessary boost for the economy, but as economists have pointed out, there was no clear benefits for the economy due to this tax cut.[60] Therefore, because they support deficit increases which do not boost the economy, they should have no good faith reason to support deficit increases which actually will improve the economy by supporting up-and-coming industries, jobs for millions of Americans, and bolstering climate action in America.

The second moment in history which should be analyzed is the 2020 coronavirus pandemic. The reason for why is because during this year, the US deficit exploded to its largest amount in history, $3.7 trillion. The reason for pointing to this moment in history is because there have been many Members in Congress, especially Republicans who we are assuming would be against these proposed deficit increases, who in the past have derided deficit increases because those proposals simply cannot be afforded. Proposals like deficit spending on infrastructure, healthcare, education, etc., have all been derided as unaffordable. Yet, just about all these same Members turned around in March of 2020 and passed a bill which blew up the deficit to nearly $4 trillion. Therefore, the question must be asked to them, what is an extra $76 billion to the deficit, or even $182 billion, when the nation can rebound from nearly $4 trillion?

The third moment in history, and this would be directed more towards Democratic Members, is the Great Depression and WWII era. The reason for why is because during this era, the debt as a percentage of GDP ratio was the highest it had ever been in American history. While it is still possible that 2020 could eclipse that statistic, it is still unclear since the 2020 GDP has not been fully calculated yet. However, given the severity of the crises in the 1930s and 1940s, between the Great Depression, the

[60] Krugman, Paul. “Why Was Trump's Tax Cut a Fizzle?” The New York Times, The New York Times, 16 Nov. 2018, www.nytimes.com/2018/11/15/opinion/tax-cut-fail-trump.html.

Dust Bowl, and World War II, there was a strong enough sentiment, and a vehement enough consensus among Members of Congress that the government needed to be adequately spending on those crises to overcome them. In history, that moment is not unlike the one that America is in now with respect to the pandemic and climate change. Therefore, there should be the sentiment among enough Members that bold and big spending is not unprecedented, and it is not a death knell for an economy, especially since when it maxed out at 106% in the mid-1940s, the American economy followed up that period with an economic era regarded as the "postwar economic boom," or the "Golden Age of Capitalism".[61]

Compromises to be made

Lastly, a handful of compromises must be made and understood when attempting to get a robust Green New Deal through Congress. While I have my own personal wish list of policies which could and should be passed, at the end of the day, my wish list is that a robust Green New Deal gets passed through Congress, not one that languishes on the floor of the Senate or the House.

There are three primary compromises which must be made. The first is one which, as stated earlier, is mentioned in the original Green New Deal resolution fact sheet, which is that nuclear must remain an integral part of the American energy system, and then when certain technologies have been developed (e.g., solar thermal, OTEC), and/or infrastructural improvements (e.g., more efficient transmission) have been developed, many if not all the nuclear reactors in America must remain operational. Nuclear energy is a clean energy, and it must continue to provide a sufficient base load capacity. But no new facilities should be developed.

The second compromise I anticipate will be a sticking point for at least the next decade or two to come in American politics, CCS. Kerry Emanuel in his book *What We Know About Climate Change* provides

[61] Condon, Christopher, and Dave Merrill. "U.S. Debt to Surge Past Wartime Record, Deficit to Quadruple." Bloomberg.com, Bloomberg, 21 Apr. 2020, www.bloomberg.com/graphics/2020-debt-and-deficit-projections-hit-records/.

important analysis about “the left.” At the end of the book, he states that nuclear power was “viewed with deep ambivalence by the left, and only a few environmentalists have begun to rethink their visceral opposition to it. Had it not been for green opposition, the United States today might derive most of its electricity from nuclear sources as France does”.[62] While the tone in this assertion does evoke that of a scolding one, there is an important truth within it, which is that if the United States embraced nuclear energy more so in the mid-to-late 20th century, the path to a net zero carbon emissions electric grid would be shorter and cheaper. Of course, it is possible that there could have been a Chernobyl or Fukishima level meltdown if nuclear energy were deployed at a larger scale, but that will never be known. Nevertheless, this is an important assertion to internalize because if CCS receives solely visceral opposition by the left, then establishing a zero carbon emissions electric grid could be take longer and be more costly, akin to how the minimized adoption of nuclear energy played out the way it did. And by the way, if the process is longer and more costly, then that is an even bigger political hill to climb.

But let me be clear, there <u>must</u> be provisions to phase out this technology as soon as possible and limit the influence of the entities behind this technology. Only then, can a robust Green New Deal get through Congress.

CONCLUSION

To recap, there are three primary takeaways from this research thesis. The first is that due to the urgency of climate change, difficult decisions must be made, and short-term sacrifices such as grey-zone mitigation approaches must be employed to maximize long term benefits. Although, I welcome any criticism and/or pushback on that notion and the specifics which I laid out, especially as more data is recorded, and more studies are published. Second, the cost of developing the zero carbon emissions electric grid facet of a Green New Deal in the United States relatively does not cost very much. Especially

[62] Emanuel, Kerry A. What We Know about Climate Change. The MIT Press, 2018., 60

given the projections that climate change may bring about the destruction of civilization, hence the destruction of the United States economy, spending tens of billions or hundreds of billions of dollars annually to mitigate that possibility seems like a wise investment/insurance policy. And third, there are avenues by which this may be achieved via post-2020 American politics. When combining the economic history of the United States, notably the deficit spending in the 1930s/1940s and in 2020 when the United States' deficit reached nearly $4 trillion, the conclusions can be drawn that the United States federal government has the capacity to spend its way out of a costly crisis.

These conclusions provide a roadmap for how to get a robust Green New Deal through Congress.

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Appendix A:

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
2030 projections																				
total elec. Demand	average demand increase	*	% of ff	*	(	avg LCOE of RE in this decade ($/MWh)	+	proj CCS LCOE by '30 ($/MWh)	)/2	*	R&D factor	=		*1000 b/c of 1000 MWh is EIA measurement				PA		
260007	1.104622125	*	0.6893853			$54.76	+ $	69.35			0.85	=	319550716	1000	3.19551E+11			PA		
															3.19551E+11	$ 319,550,716,067.77		PA	10 yrs cost	$ 55,346,184,023
total elec. Demand	average demand increase	*	% of ff	*	(	avg LCOE of RE in this decade ($/MWh)	+	proj CCS LCOE by '30 ($/MWh)	)/2	*	R&D factor	=		*1000 b/c of 1000 MWh is EIA measurement				MA		
30063	1.104622125	*	0.874497			$54.76	+ $	69.35			0.85	=	46868752	1000	46868751616			MA		
															46868751616	$ 46,868,751,616.25		MA	10 yrs cost	$ 8,117,667,780
total elec. Demand	average demand increase	*	% of ff	*	(	avg LCOE of RE in this decade ($/MWh)	+	proj CCS LCOE by '30 ($/MWh)	)/2	*	R&D factor	=		*1000 b/c of 1000 MWh is EIA measurement				KS		
57783	1.104622125	*	0.514753			$54.76	+ $	69.35			0.85	=	53026348	1000	53026347975			KS		
															53026347975	$ 53,026,347,974.62		KS	10 yrs cost	$ 9,184,163,469
total elec. Demand	average demand increase	*	% of ff	*	(	avg LCOE of RE in this decade ($/MWh)	+	proj CCS LCOE by '30 ($/MWh)	)/2	*	R&D factor	=		*1000 b/c of 1000 MWh is EIA measurement				OR		
61831	1.104622125	*	0.291763			$54.76	+ $	69.35			0.85	=	32160977	1000	32160976851			OR		
															32160976851	$ 32,160,976,851.22		OR	10 yrs cost	$ 5,570,281,191
total elec. Demand	average demand increase	*	% of ff	*	(	avg LCOE of RE in this decade ($/MWh)	+	proj CCS LCOE by '30 ($/MWh)	)/2	*	R&D factor	=		*1000 b/c of 1000 MWh is EIA measurement				CA		
214192	1.104622125	*	0.462356			$54.76	+ $	69.35			0.85	=	176551938	1000	1.76552E+11			CA		
															1.76552E+11	$ 176,551,937,942.98		CA	10 yrs cost	$ 30,578,795,652
															avg per state	125,631,746,091				
															total for 50 states	6.28159E+12		USA	USA	
															Total cost on American society	6,281,587,304,528.39		USA	USA	
															% of total $ in tax credits (.1732)	1.08797E+12	$ 1,087,970,921,144.32	paid for by the govt.		
															annual spending for tax credits	1.08797E+11	$ 108,797,092,114.43	/annualy		

2040 projections

total elec. Demand	average demand increase	*	% of ff	. avg LCOE of RE in these decades ($/MWh)	+	proj CCS LCOE by '30 ($/MWh)	*	R&D factor		*1000 b/c of 1000 MWh is EIA measurement				PA	PA
260007	1.22019004	*	0.689385286	52.235	+	$60		0.85	291324027.3	1000	2.91324E+11			PA	PA
												342,734,149,782		PA	PA
total elec. Demand	average demand increase	*	% of ff	. avg LCOE of RE in this decade ($/MWh)	+	proj CCS LCOE by '30 ($/MWh)	*	R&D factor		*1000 b/c of 1000 MWh is EIA measurement				MA	MA
30063	1.22019004	*	0.874497	52.235	+	$60		0.85	42728721.26	1000	42728721262			MA	MA
												50,269,083,838		MA	MA
total elec. Demand	average demand increase	*	% of ff	. avg LCOE of RE in this decade ($/MWh)	+	proj CCS LCOE by '30 ($/MWh)	*	R&D factor		*1000 b/c of 1000 MWh is EIA measurement				KS	KS
57783	1.22019004	*	0.514753	52.235	+	$60		0.85	48342402.22	1000	48342402220			KS	KS
												56,873,414,376		KS	KS
total elec. Demand	average demand increase	*	% of ff	. avg LCOE of RE in this decade ($/MWh)	+	proj CCS LCOE by '30 ($/MWh)	*	R&D factor		*1000 b/c of 1000 MWh is EIA measurement				OR	OR
61831	1.22019004	*	0.291763	52.235	+	$60		0.85	29320119.87	1000	29320119867			OR	OR
												34,494,258,667		OR	OR
total elec. Demand	average demand increase	*	% of ff	avg LCOE of RE in this decade ($/MWh)	+	proj CCS LCOE by '30 ($/MWh)	*	R&D factor		*1000 b/c of 1000 MWh is EIA measurement				CA	CA
214192	1.22019004	*	0.462356	52.235	+	$60		0.85	160956677.6	1000	1.60957E+11			CA	CA
												189,360,797,209		CA	CA
											avg per state	**114,534,389,658**		USA	USA
											total for 50 states	**5.72672E+12**		USA	USA
											Total cost on American society	**5,726,719,482,921.32**		USA	USA
											% of total $ in tax credits	**9.91868E+11**	**$ 991,867,814,441.97**		
											annual spending for tax credit	**49593390722**	**$ 49,593,390,722.10**		

2030 projections w/ 1/3s transit, 2/3 Evs

									the /2 is to find the average between RE and CCS						
total elec.	average de	*	% of ff	.	avg LCOE c	+	proj CCS L(*	R&D factor		*1000 b/c of 1000 MWh is EIA measurement				PA	PA
342859	1.104622	*	0.689385		$54.76	+	$ 69.35	0.85	4.21E+08	1000	4.21376E+11			PA	PA
											4.21376E+11	**512,762,164,102**		PA	PA
total elec.	average de	*	% of ff	.	avg LCOE c	+	proj CCS L(*	R&D factor		*1000 b/c of 1000 MWh is EIA measurement				MA	MA
112915	1.104622	*	0.874497		$54.76	+	$ 69.35	0.85	1.76E+08	1000	1.76036E+11			MA	MA
											1.76036E+11	**255,152,742,157**		MA	MA
total elec.	average de	*	% of ff	.	avg LCOE c	+	proj CCS L(*	R&D factor		*1000 b/c of 1000 MWh is EIA measurement				KS	KS
140635	1.104622	*	0.514753		$54.76	+	$ 69.35	0.85	1.29E+08	1000	1.29058E+11			KS	KS
											1.29058E+11	**178,239,922,979**		KS	KS
total elec.	average de	*	% of ff	.	avg LCOE c	+	proj CCS L(*	R&D factor		*1000 b/c of 1000 MWh is EIA measurement				OR	OR
144683	1.104622	*	0.291763		$54.76	+	$ 69.35	0.85	75255885	1000	75255884811			OR	OR
											75255884811	**103,348,462,958**		OR	OR
total elec.	average de	*	% of ff	.	avg LCOE c	+	proj CCS L(*	R&D factor		*1000 b/c of 1000 MWh is EIA measurement				CA	CA
297044	1.104622	*	0.462356		$54.76	+	$ 69.35	0.85	2.45E+08	1000	2.44844E+11			CA	CA
											2.44844E+11	**302,257,281,892**		CA	CA
Energy addition (EVs + Transit)											**avg per state**	**209,314,245,392**		USA	USA
((5.918 * 1000000)/50 * 2/3) + (((5.918 * 1000000)/50 * 1/3)*.1)						=	**82852**				**total for 50 states**	**1.04657E+13**		USA	USA
							^added into total				**Total cost on American society**	**10,465,712,269,624.80**		USA	USA
											% of total $ in tax credits	**1.81266E+12**	**$ 1,812,661,365,099.01**	paid for by the govt.	
											Annual spending	**1.81266E+11**	**$ 181,266,136,509.90**		

2030 projections w/ 2/3s transit, 1/3 Evs

									the /2 is to find the average between RE and CCS						
total elec.	average de	*	% of ff	.	avg LCOE c	+	proj CCS L(*	R&D factor		*1000 b/c of 1000 MWh is EIA measurement				PA	PA
307351	1.104622	*	0.689385		$54.76	+	$ 69.35	0.85	3.78E+08	1000	3.77737E+11			PA	PA
											3.77737E+11	**512,762,164,102**		PA	PA
total elec.	average de	*	% of ff	.	avg LCOE c	+	proj CCS L(*	R&D factor		*1000 b/c of 1000 MWh is EIA measurement				MA	MA
77407	1.104622	*	0.874497		$54.76	+	$ 69.35	0.85	1.21E+08	1000	1.20679E+11			MA	MA
											1.20679E+11	**255,152,742,157**		MA	MA
total elec.	average de	*	% of ff	.	avg LCOE c	+	proj CCS L(*	R&D factor		*1000 b/c of 1000 MWh is EIA measurement				KS	KS
105127	1.104622	*	0.514753		$54.76	+	$ 69.35	0.85	96473026	1000	96473026384			KS	KS
											96473026384	**178,239,922,979**		KS	KS
total elec.	average de	*	% of ff	.	avg LCOE c	+	proj CCS L(*	R&D factor		*1000 b/c of 1000 MWh is EIA measurement				OR	OR
109175	1.104622	*	0.291763		$54.76	+	$ 69.35	0.85	56786639	1000	56786638543			OR	OR
											56786638543	**103,348,462,958**		OR	OR
total elec.	average de	*	% of ff	.	avg LCOE c	+	proj CCS L(*	R&D factor		*1000 b/c of 1000 MWh is EIA measurement				CA	CA
261536	1.104622	*	0.462356		$54.76	+	$ 69.35	0.85	2.16E+08	1000	2.15576E+11			CA	CA
											2.15576E+11	**302,257,281,892**		CA	CA
											avg per state	**173,450,317,120**		USA	USA
Energy addition (EVs + Transit)											**total for 50 states**	**8.67252E+12**		USA	USA
((5.918 * 1000000)/50 * 1/3) + (((5.918 * 1000000)/50 * 2/3)*.1 =							**47344**				**Total cost on American society**	**8,672,515,856,012.03**		USA	USA
							^added into total				**% of total $ in tax credits**	**1.50208E+12**	**$1,407,861,333,914.69**	paid for by the govt.	
											Annual spending	**1.50208E+11**	**$ 140,786,133,391.47**		

2040 projections w/ 1/3s transit, 2/3 Evs

total elec.	average de	*	% of ff	.	avg LCOE c	+	proj CCS L(	*	R&D factor		*1000 b/c of 1000 MWh is EIA measurement				PA	PA
342859	1.22019	*	0.689385		**52.235**	+	$66.83		0.85	427884968	1000	4.27885E+11			PA	PA
													498,753,079,920		PA	PA
total elec.	average de	*	% of ff	.	avg LCOE c	+	proj CCS L(	*	R&D factor		*1000 b/c of 1000 MWh is EIA measurement				MA	MA
112915	1.22019	*	0.874497		**52.235**	+	$66.83		0.85	178755506	1000	1.78756E+11			MA	MA
													248,181,759,323		MA	MA
total elec.	average de	*	% of ff	.	avg LCOE c	+	proj CCS L(	*	R&D factor		*1000 b/c of 1000 MWh is EIA measurement				KS	KS
140635	1.22019	*	0.514753		**52.235**	+	$66.83		0.85	131051432	1000	1.31051E+11			KS	KS
													173,370,261,642		KS	KS
total elec.	average de	*	% of ff	.	avg LCOE c	+	proj CCS L(	*	R&D factor		*1000 b/c of 1000 MWh is EIA measurement				OR	OR
144683	1.22019	*	0.291763		**52.235**	+	$66.83		0.85	76418267	1000	76418267425			OR	OR
													100,524,897,923		OR	OR
total elec.	average de	*	% of ff	.	avg LCOE c	+	proj CCS L(	*	R&D factor		*1000 b/c of 1000 MWh is EIA measurement				CA	CA
297044	1.22019	*	0.462356		**52.235**	+	$66.83		0.85	248626118	1000	2.48626E+11			CA	CA
													293,999,364,278		CA	CA
Energy addition (EVs + Transit)												**avg per state**	**212,547,258,202**		USA	USA
((5.918 * 1000000)/50 * 2/3) + (((5.918 * 1000000)/50 * 1/3)*.1)						=	**82852**					**total for 50 states**	**1.06274E+13**		USA	USA
							^added into total					**Total cost on American society**	**10,627,362,910,109.50**		USA	USA
												% of total $ in tax credits	**1.84066E+12**	**$ 1,840,659,256,030.97**		
												Annual spending	**92032962802**	**$ 92,032,962,801.55**		

2040 projections w/ 2/3s transit, 1/3 Evs

total elec.	average de	*	% of ff	.	avg LCOE c	+	proj CCS L(	*	R&D factor		*1000 b/c of 1000 MWh is EIA measurement				PA	PA
307351	1.22019	*	0.689385		**52.235**	+	$66.83		0.85	3.84E+08	1000	3.83571E+11			PA	PA
													498,753,079,920		PA	PA
total elec.	average de	*	% of ff	.	avg LCOE c	+	proj CCS L(	*	R&D factor		*1000 b/c of 1000 MWh is EIA measurement				MA	MA
77407	1.22019	*	0.874497		**52.235**	+	$66.83		0.85	1.23E+08	1000	1.22543E+11			MA	MA
													248,181,759,323		MA	MA
total elec.	average de	*	% of ff	.	avg LCOE c	+	proj CCS L(	*	R&D factor		*1000 b/c of 1000 MWh is EIA measurement				KS	KS
105127	1.22019	*	0.514753		**52.235**	+	$66.83		0.85	97963123	1000	97963123388			KS	KS
													173,370,261,642		KS	KS
total elec.	average de	*	% of ff	.	avg LCOE c	+	proj CCS L(	*	R&D factor		*1000 b/c of 1000 MWh is EIA measurement				OR	OR
109175	1.22019	*	0.291763		**52.235**	+	$66.83		0.85	57663750	1000	57663750034			OR	OR
													100,524,897,923		OR	OR
total elec.	average de	*	% of ff	.	avg LCOE c	+	proj CCS L(	*	R&D factor		*1000 b/c of 1000 MWh is EIA measurement				CA	CA
261536	1.22019	*	0.462356		**52.235**	+	$66.83		0.85	2.19E+08	1000	2.18906E+11			CA	CA
													293,999,364,278		CA	CA
Energy addition (EVs + Transit)												**avg per state**	**176,129,385,122**		USA	USA
((5.918 * 1000000)/50 * 1/3) + (((5.918 * 1000000)/50 * 2/3)*.1)						=	**47344**					**total for 50 states**	**8.80647E+12**		USA	USA
							^added into total					**Total cost on American society**	**8,806,469,256,088.52**		USA	USA
												% of total $ in tax credits	**1.52528E+12**	**$ 1,525,280,475,154.53**		
												Annual spending	**76264023758**	**$ 76,264,023,757.73**		

2030 projections w/ 100% Evs

	2.7 billion MWh * $45/Mwh = ~$122 billion											
total elec. Demand	average demand increase	* % of ff	. avg LCOE of RE in this decade ($/MWh)	+ proj CCS LCOE by '30 ($/MWh)	* R&D factor		*1000 b/c of 1000 MWh is EIA measurement				PA	PA
378367	1.104622125 *	0.689385	$54.76 +	$65	0.85	4.36E+08	1000	4.35848E+11			PA	PA
								4.35848E+11	512,762,164,102		PA	PA
total elec. Demand	average demand increase	* % of ff	. avg LCOE of RE in this decade ($/MWh)	+ proj CCS LCOE by '30 ($/MWh)	* R&D factor		*1000 b/c of 1000 MWh is EIA measurement				MA	MA
148423	1.104622125 *	0.874497	$54.76 +	$65	0.85	2.17E+08	1000	2.1688E+11			MA	MA
								2.1688E+11	255,152,742,157		MA	MA
total elec. Demand	average demand increase	* % of ff	. avg LCOE of RE in this decade ($/MWh)	+ proj CCS LCOE by '30 ($/MWh)	* R&D factor		*1000 b/c of 1000 MWh is EIA measurement				KS	KS
176143	1.104622125 *	0.514753	$54.76 +	$65	0.85	1.52E+08	1000	1.51504E+11			KS	KS
								1.51504E+11	178,239,922,979		KS	KS
total elec. Demand	average demand increase	* % of ff	. avg LCOE of RE in this decade ($/MWh)	+ proj CCS LCOE by '30 ($/MWh)	* R&D factor		*1000 b/c of 1000 MWh is EIA measurement				OR	OR
180191	1.104622125 *	0.291763	$54.76 +	$65	0.85	87846194	1000	87846193514			OR	OR
								87846193514	103,348,462,958		OR	OR
total elec. Demand	average demand increase	* % of ff	. avg LCOE of RE in this decade ($/MWh)	+ proj CCS LCOE by '30 ($/MWh)	* R&D factor		*1000 b/c of 1000 MWh is EIA measurement				CA	CA
332552	1.104622125 *	0.462356	$54.76 +	$65	0.85	2.57E+08	1000	2.56919E+11			CA	CA
								2.56919E+11	302,257,281,892		CA	CA
	5.918											
	1000000							avg per state	229,799,297,595		USA	USA
	50							total for 50 states	1.149E+13		USA	USA
EV addition per state	118360							Total cost on American society	11,489,964,879,746.70		USA	USA
								% of total $ in tax credits	1.99006E+12	$ 1,990,061,917,172.14	paid for by the govt.	
								annual spending for tax credits	1.99006E+11	$ 199,006,191,717.21	/annualy	

2040 projections w/ 100% Evs

total elec.	average demand increase *	% of ff .	avg LCOE of RE in these decades ($/MWh) +	proj CCS LCOE by '30 ($/MWh) *	R&D factor		*1000 b/c of 1000 MWh is EIA measurement				PA	PA
378367	1.22019004 *	0.689385	52.235 +	$60	0.85	4.24E+08	1000	4.2394E+11			PA	PA
									498,753,079,920		PA	PA
total elec.	average demand increase *	% of ff .	avg LCOE of RE in this decade ($/MWh) +	proj CCS LCOE by '30 ($/MWh) *	R&D factor		*1000 b/c of 1000 MWh is EIA measurement				MA	MA
148423	1.22019004 *	0.874497	52.235 +	$60	0.85	2.11E+08	1000	2.10954E+11			MA	MA
									248,181,759,323		MA	MA
total elec.	average demand increase *	% of ff .	avg LCOE of RE in this decade ($/MWh) +	proj CCS LCOE by '30 ($/MWh) *	R&D factor		*1000 b/c of 1000 MWh is EIA measurement				KS	KS
176143	1.22019004 *	0.514753	52.235 +	$60	0.85	1.47E+08	1000	1.47365E+11			KS	KS
									173,370,261,642		KS	KS
total elec.	average demand increase *	% of ff .	avg LCOE of RE in this decade ($/MWh) +	proj CCS LCOE by '30 ($/MWh) *	R&D factor		*1000 b/c of 1000 MWh is EIA measurement				OR	OR
180191	1.22019004 *	0.291763	52.235 +	$60	0.85	85446163	1000	85446163234			OR	OR
									100,524,897,923		OR	OR
total elec.	average demand increase *	% of ff .	avg LCOE of RE in this decade ($/MWh) +	proj CCS LCOE by '30 ($/MWh) *	R&D factor		*1000 b/c of 1000 MWh is EIA measurement				CA	CA
332552	1.22019004 *	0.462356	52.235 +	$60	0.85	2.5E+08	1000	2.49899E+11			CA	CA
									293,999,364,278		CA	CA
	5.918							avg per state	223,520,991,725		USA	USA
	1000000							total for 50 states	1.1176E+13		USA	USA
	50							Total cost on American society	11,176,049,586,231.20		USA	USA
EV additio	118360							% of total $ in tax credits	1.93569E+12	$ 1,935,691,788,335.24		
								annual spending for tax credits	96784589417	$ 96,784,589,416.76		

- The “total elec. Demand” variables were pulled from the EIA’s monthly electricity demand report per state and multiplied by 11. Since the latest month (with the most up to date data) was July, I decided to multiply by 11 because July is a summer month which means that the electricity demand is at its annual peak. Therefore, multiplying by 11 provides us an accurate estimate of the annual energy demand of a state
- The equations for all projections follow the same fundamental equation laid out in the first projection “2030 projections”. This is the case even though the mathematical symbols are not

seen in the rest of the following projection images. The purpose for these visual omissions was to be able to fit the rest of the equations horizontally.

- The equations involving EV addition involves values pulled from EIA

Appendix B:

RETC:

Because the LCOE for solar energy (utility and residential average) is $32.80, and...

$32.80/MWh = x * (1-.2) = $41/MWh, is the projected solar LCOE without an ITC

$41/MWh - $32.80/MWh = $8.20/MWh is essentially the tax credit provided to solar. And, because $15/MWh is the tax credit provided to wind energy, the average tax credit provided to renewables is

= ($15/MWh + $8.20/MWh)/2 = $11.6/MWh →

Cost paid by government:

$55.37 is the average "renewable energy LCOE" (RELCOE) w/ a tax credit. So, without it it is...

$11.6/MWh + $55.37/MWh = $66.97/MWh

($11.60/MWh) / ($66.97/MWh) = 0.173212 * 100 = 17.32 →

BTUs → MWh

Conversions: 1 BTU = 1055.06 J, 1 J = $2.77778 * 10^{-10}$ MWh

26,000,000,000,000 BTU * (1055.06 J/1 BTU) = $2.638 * 10^{16}$ J

$2.638 * 10^{16}$ J * ($2.77778 * 10^{-10}$ MWh/1 J) = 7,327,000 MWh

Amount of MWh from automobiles

7,327,000 * .81 = 5,918,000 MWh